The ALICE experiment

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(heavily based on a presentation

by Christoph Blume, thanks!)

Monbachtal, Sep-2007

Outline

- ***Heavy ion physics at LHC***
- ***ALICE detector setup***
- ***Physics topics and performance***
- ***Running plans***

Sources of information

- ***1995 ALICE Technical Proposal***

  CERN-LHCC 95-71

- ***Physics Performance Report, Volume I***

  J.Phys.G 30(2004)1517-1763

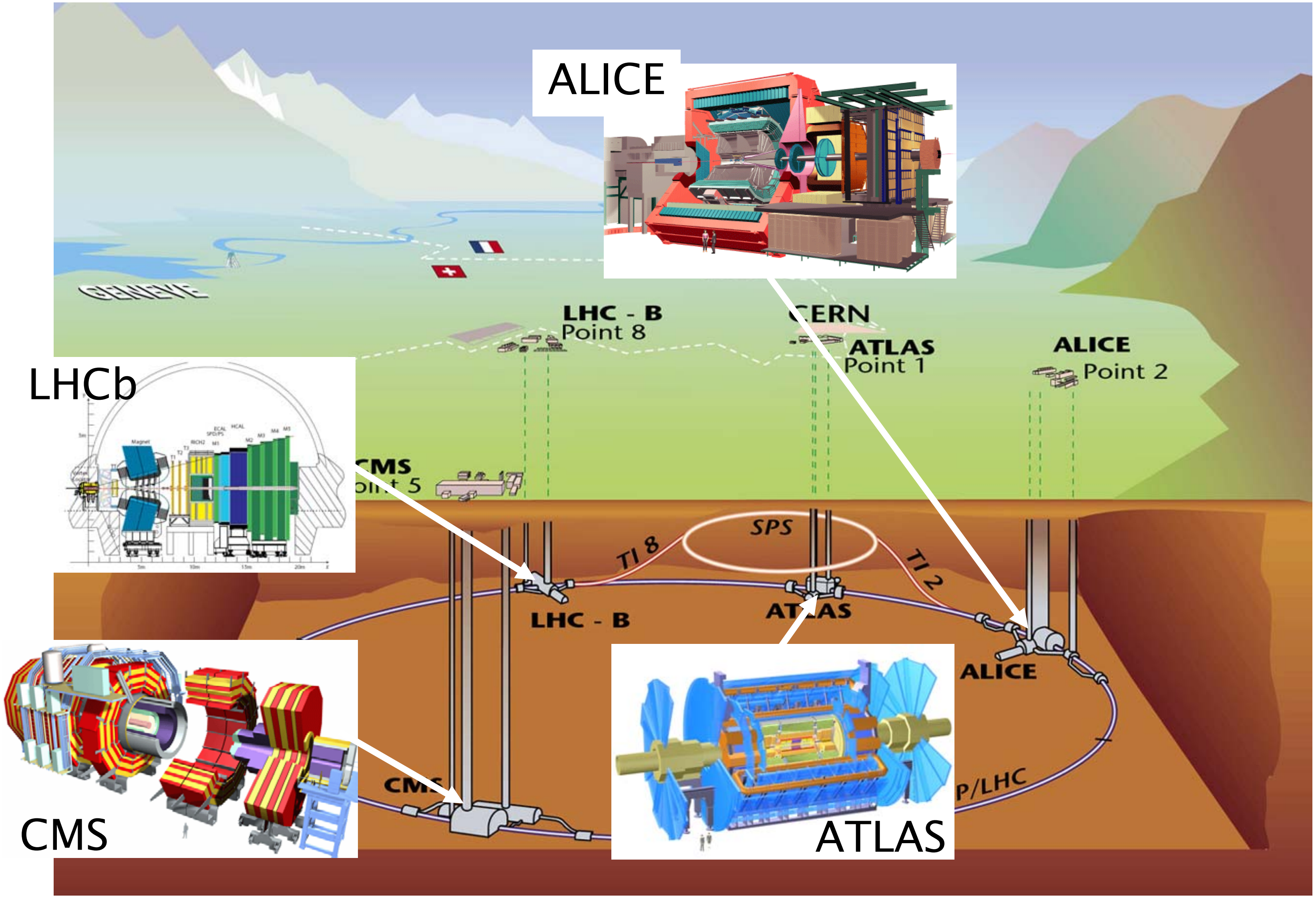
  physics topics, LHC conditions, detector summary, computing

- ***Physics Performance Report, Volume II***

  J.Phys.G 32(2006)1295-2040

  combined detector performance, event reconstruction

LHC experiments



physics questions at LHC

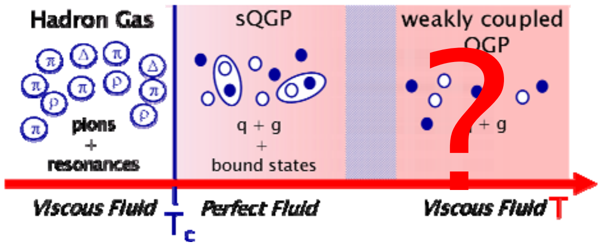
***ATLAS, CMS, LHCb*:**
electroweak symmetry breaking
origin of mass of quarks and gauge bosons
supersymmetric particles
CP violation

***ALICE*:**
chiral symmetry breaking
origin of mass of hadrons
deconfinement
hadronization

***ALL*:**
understanding high energy nuclear interactions
(input needed for cosmic ray studies)

ALICE programme

***mission*:**
create quark-gluon matter
study its properties quantitatively
be prepared for unexpected = be versatile



***methods*:**
spectra and correlations of various particles

e.g. heavy quarks (open beauty, upsilon-states)
jets in heavy ion environment
weakly interacting probes (Z^0, $W^{\pm}$)

***special at LHC*:**
higher energy density
larger system
more heavy quarks and jets
weak probes W/Z available
access to lower x

	SPS	RHIC	LHC
$\sqrt{s_{NN}}$ (GeV)	17	200	5500
dN_{ch}/dy	~450	~850	1500-4000
ε(GeV/fm³)	3	5	15-60
τ_{QGP} (fm/c)	≤ 2	2-4	≥ 10

Detector Requirements

Robust tracking performance

- Needs to digest highest multiplicities (O(10^5) tracks !)

Need to cover low p_t region (~100 MeV/c)

- Soft physics important for event characterization

But the high p_t region as well (>100 GeV/c)

- Hard probes transmit information about early phase

Good PID capabilities over large p_t-range essential

- Many effects are flavour dependent

Sensitivity to rare probes

- Heavy flavour, quarkonia, photons, ...

The Alice Collaboration

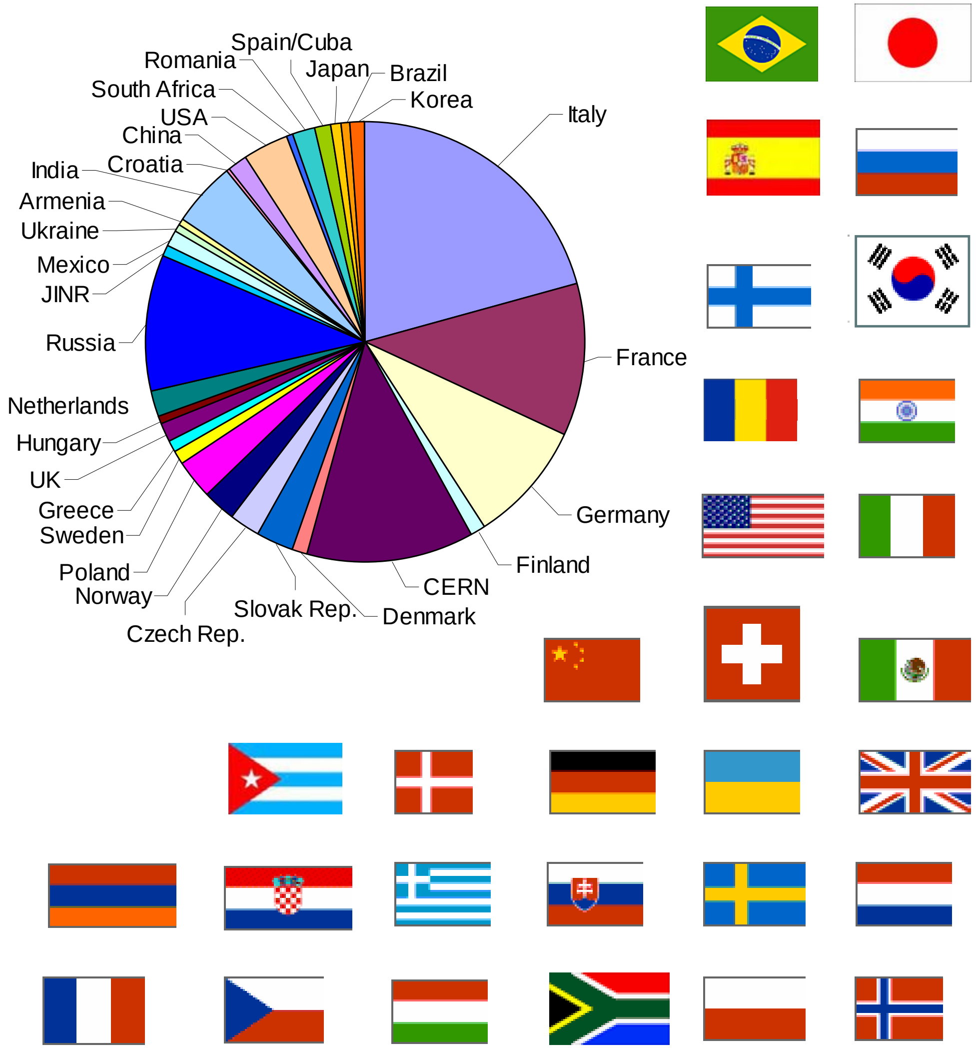
Some numbers:

Members: ca. 1000
Institutes: ca. 100
Countries: 30

Costs: 150MChF
(+ free magnet)

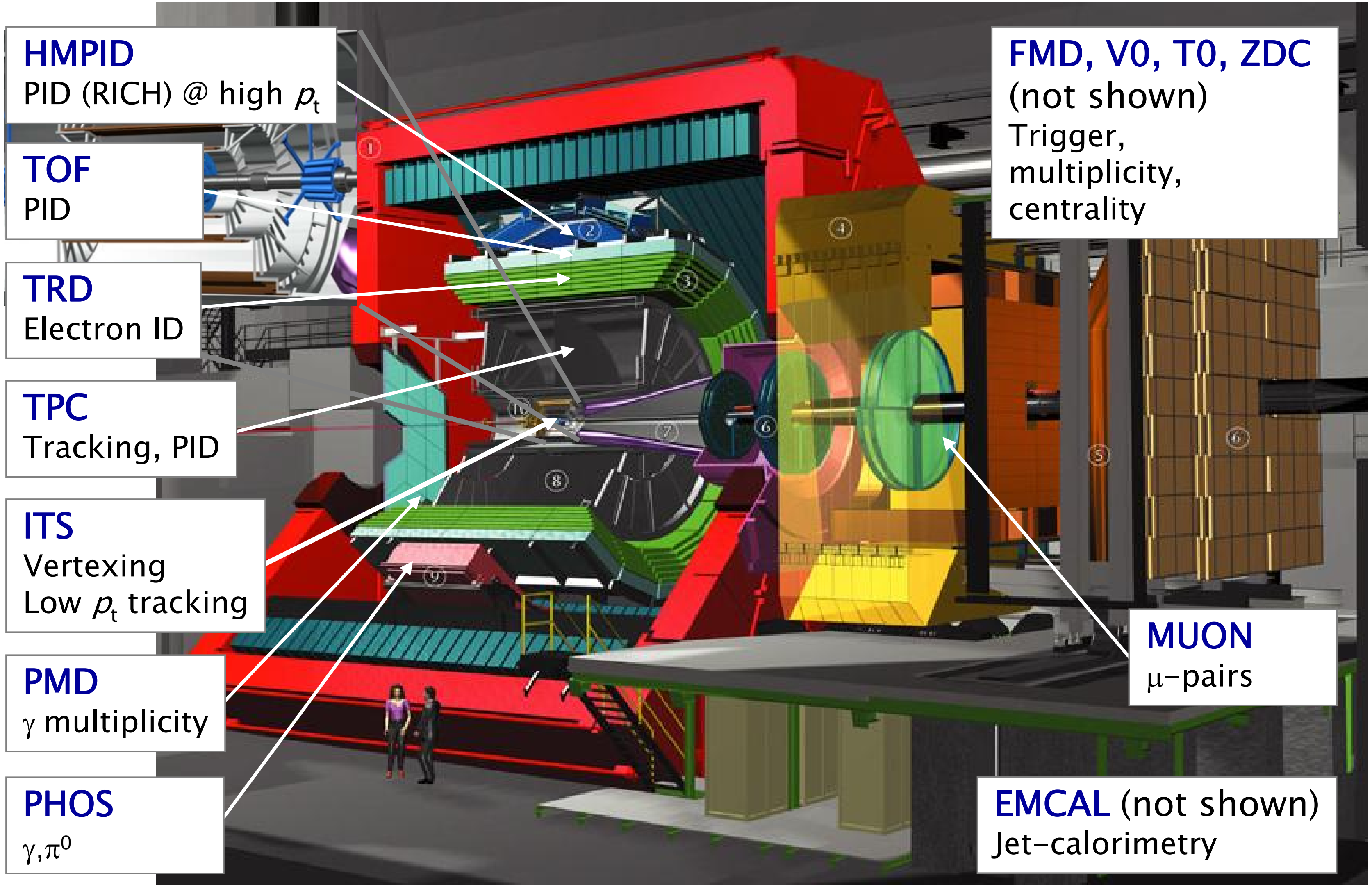
German institutions:

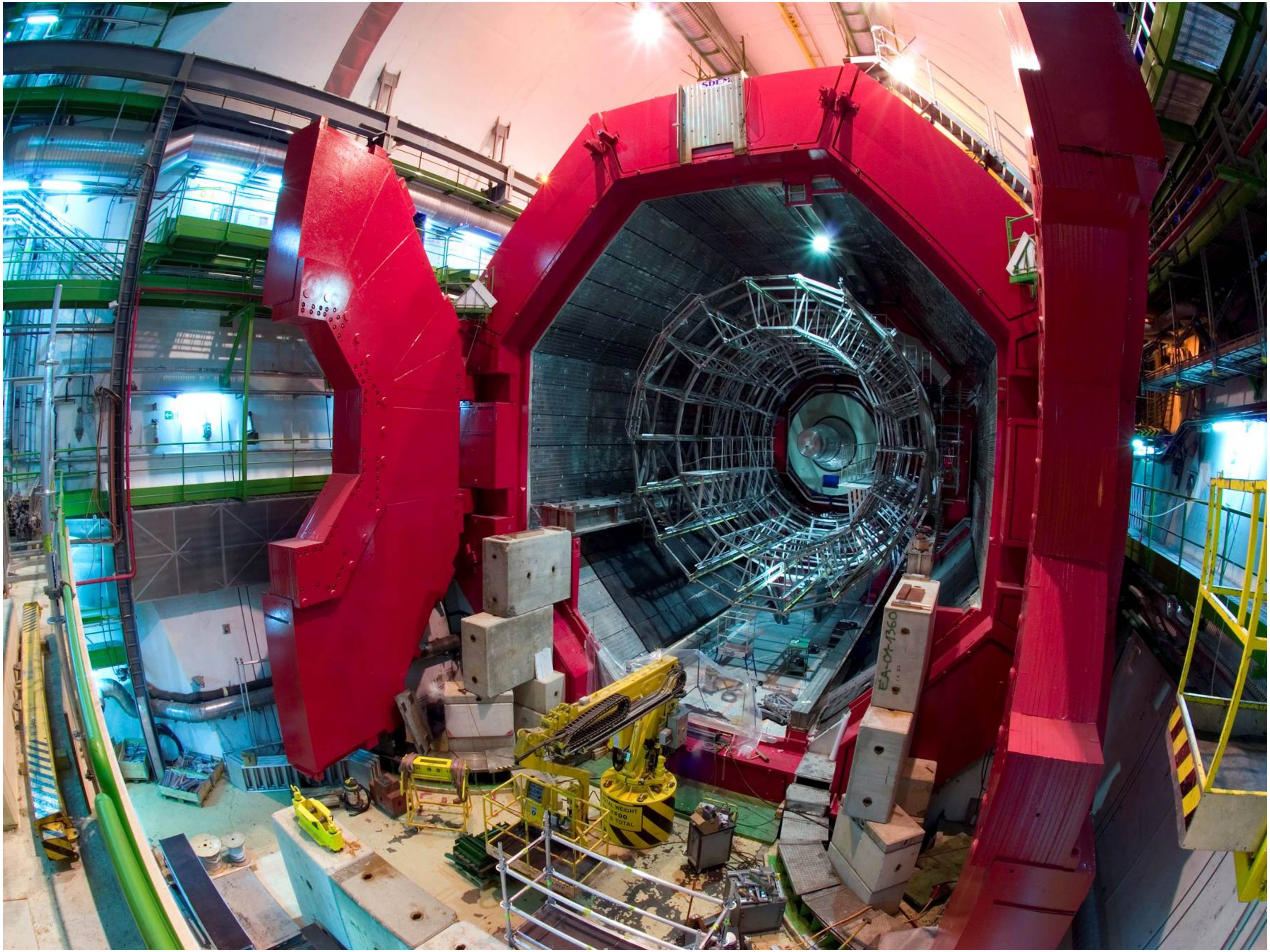
GSI Darmstadt
TU Darmstadt
Universität Frankfurt
Universität Heidelberg
FZK Karlsruhe
FH Köln
Universität Münster
FH Worms



Alice Detector

height: 16 m ***length 26 m*** ***weight: 10,000 tons*** ***price: 10 € / kg***




EA-04-1360

Acceptance for Charged Hadrons

- ***central barrel** -0.9 < η < 0.9*

  ITS,TPC,TRD,TOF 2 π tracking, PID

  HMPID single arm RICH

  PHOS single arm EM cal

  EMCAL jet calorimeter (proposed)

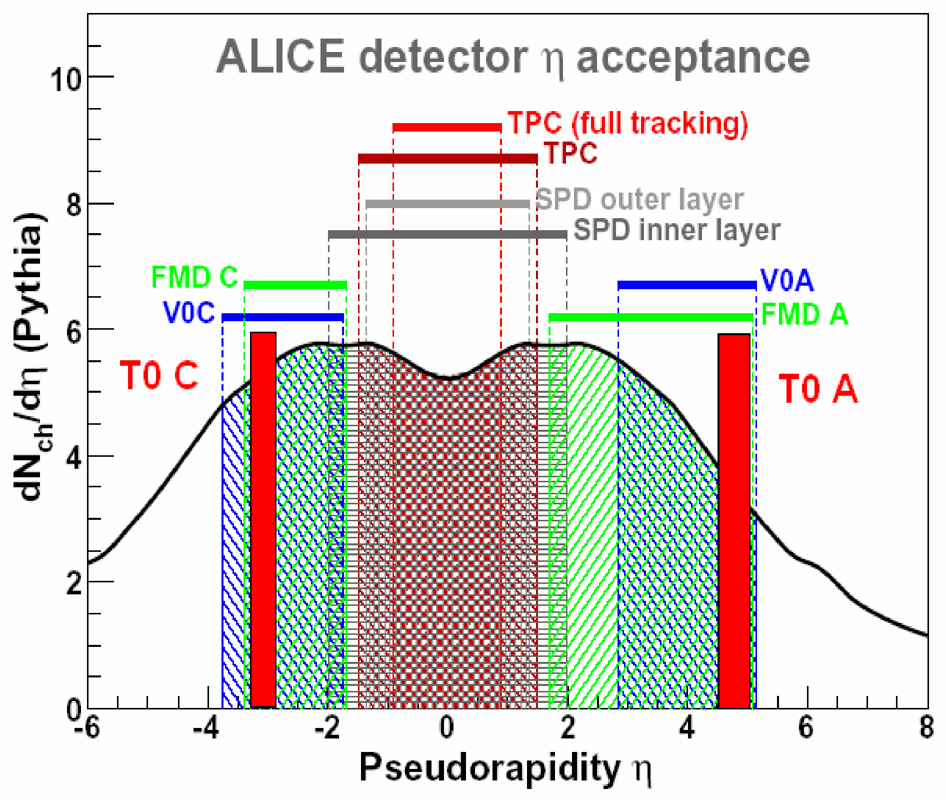
- ***forward muon arm** 2.4 < η < 4*

  absorber, 3 Tm dipole magnet
  10 tracking + 4 trigger chambers

- ***multiplicity** -5.4 < η < 3*

  PMD including photon counting

- ***trigger & timing***
  - *FMD: silicon strip multiplicity det*
  - *T0: ring of quartz window PMT's*
  - *V0: ring of scintillator paddles*
  - *6 Zero Degree Calorimeters*

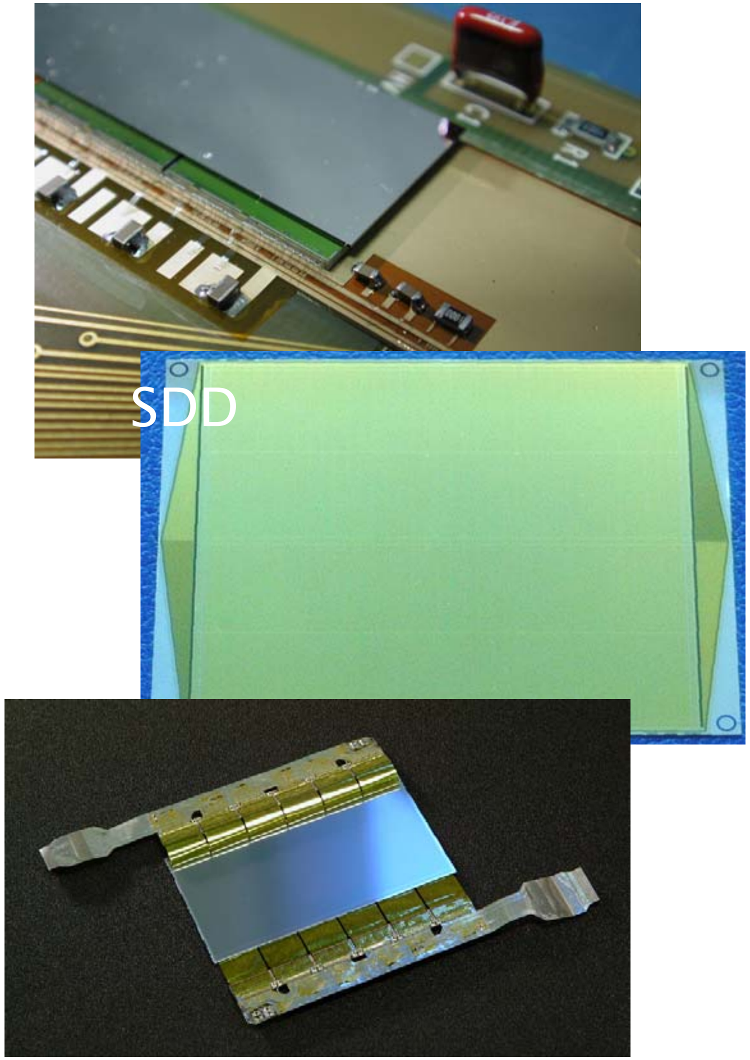


Inner Tracking System (ITS)

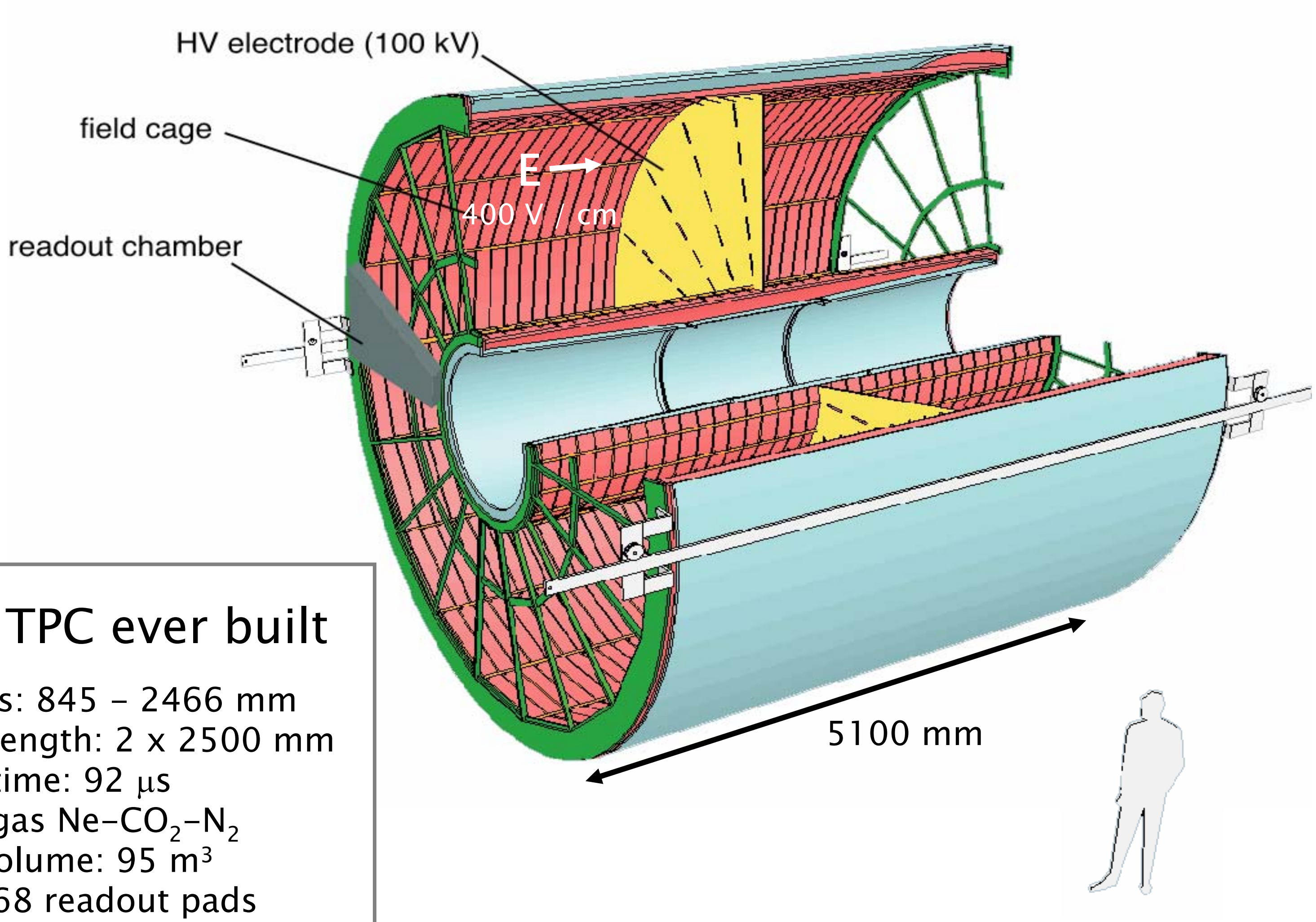
6 Layers with three different detector technologies:

Silicon Pixel Detector
Silicon Drift Detector
Silicon Strip Detector
ITS = SPD+SDD+SSD

Layer		*R (cm)*	*$\sigma r\phi$ (μm)*	*σZ (μm)*
1	*SPD*	*4*	*12*	*100*
2	*SPD*	*8*	*12*	*100*
3	*SDD*	*15*	*38*	*28*
4	*SDD*	*24*	*38*	*28*
5	*SSD*	*38*	*17*	*800*
6	*SSD*	*43*	*17*	*800*



Time Projection Chamber (TPC)



Largest TPC ever built

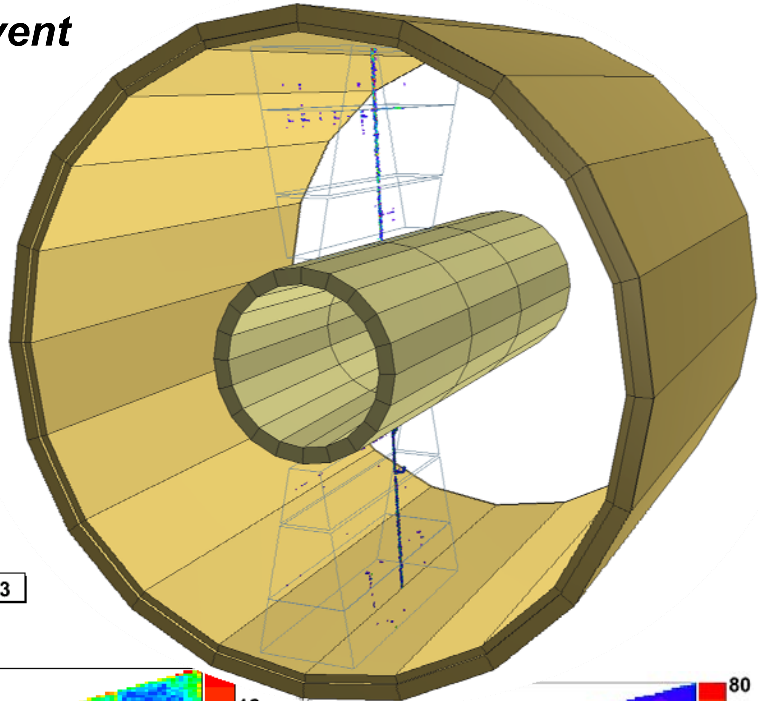
Radius: 845 – 2466 mm
Drift length: 2 x 2500 mm
Drift time: 92 μs
Drift gas Ne–CO_2–N_2
Gas volume: 95 m^3
557568 readout pads
Material: (η=0) 3% X_0

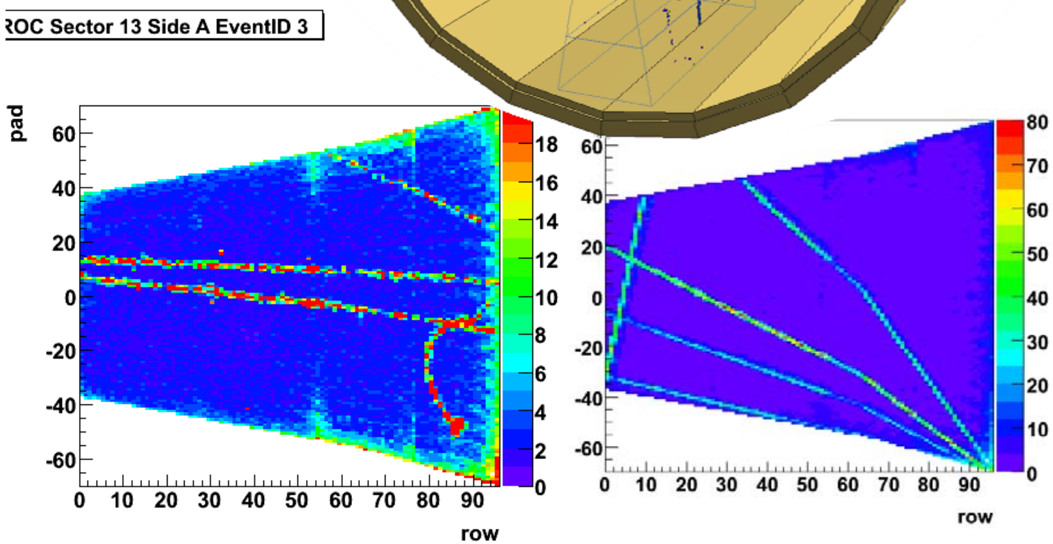
TPC

TPC assembled and installed

- Commissioning on ground
- Performance according to design specifications
- Ongoing: Installation of services
- Final commisioning until 11/2007

Cosmics event May 2006





Transition Radiation Detector (TRD)

Purpose:

Electron-ID

Quarkonia $\rightarrow e^+e^-$
Heavy flavour

Some numbers:

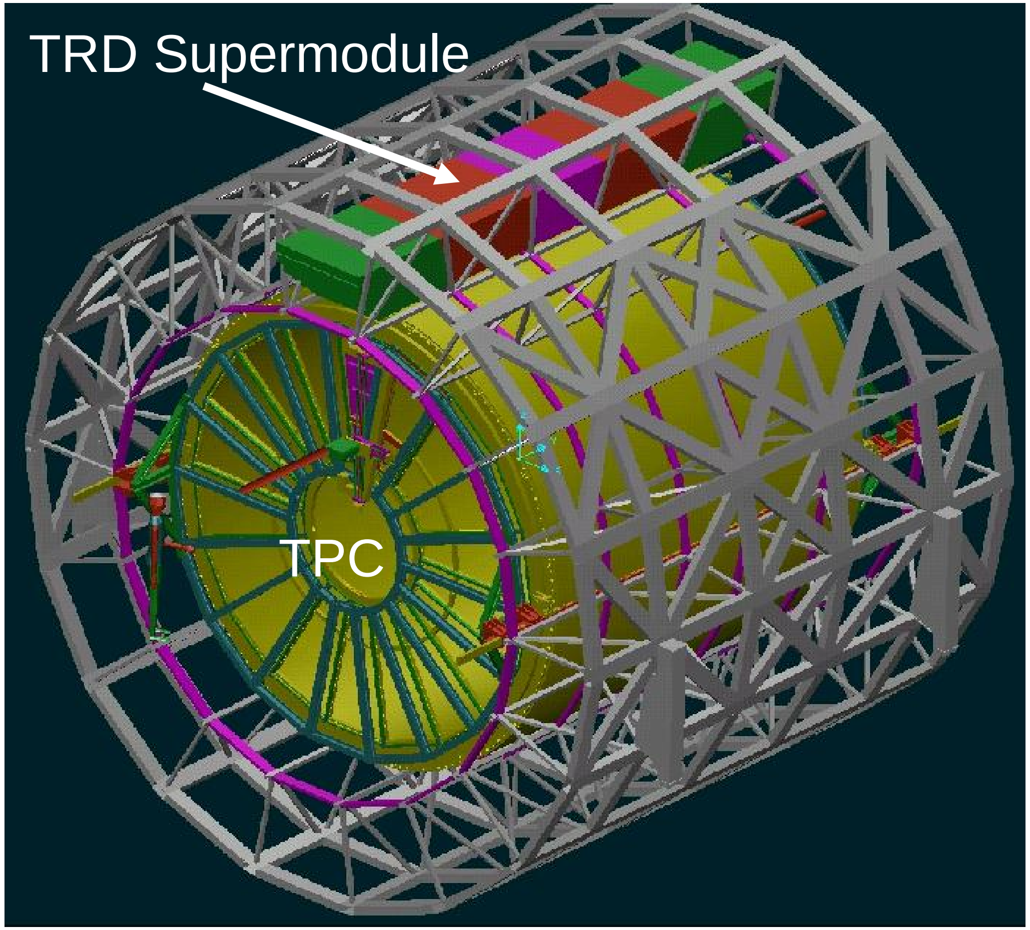
540 chambers

Total area: 736 m^2
(3 tennis courts)

Gas volume: 27.2 m^3

Resolution
($r\varphi$) 400 μm

Number of read out channels: 1.2×10^6



Transition Radiation Detector (TRD)

Drift chamber

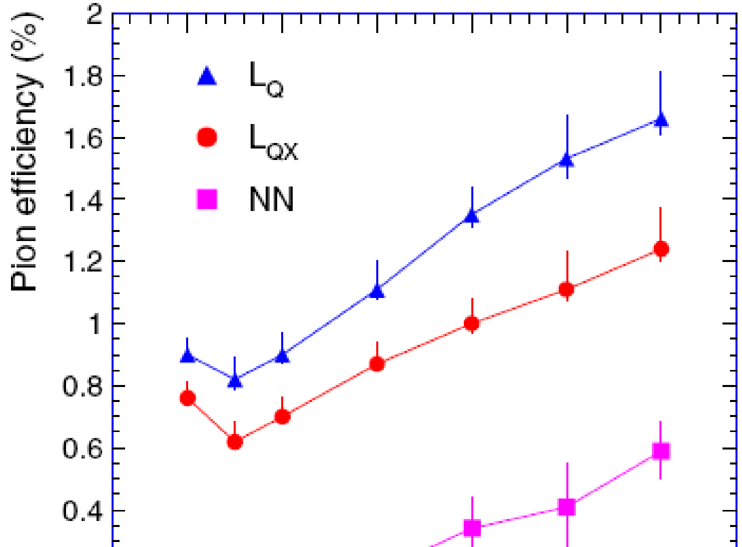
Gas: Xe–CO_2
Drift length: 3cm

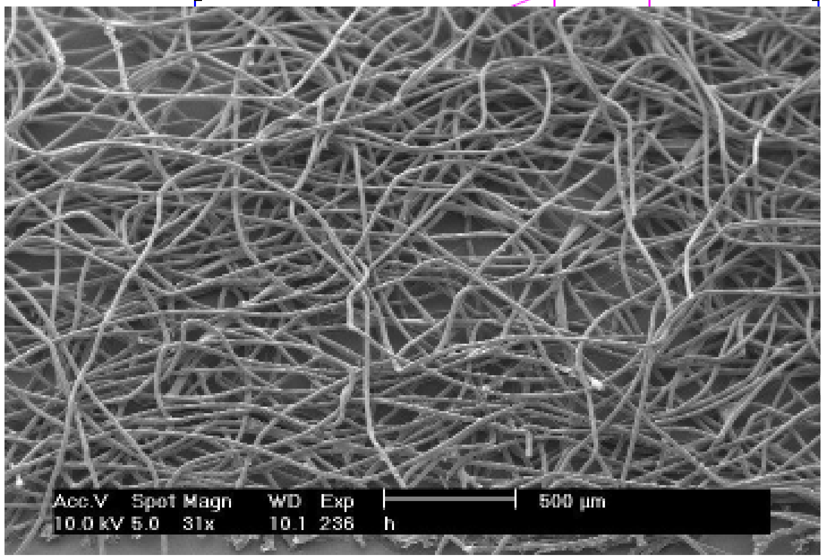
Radiator

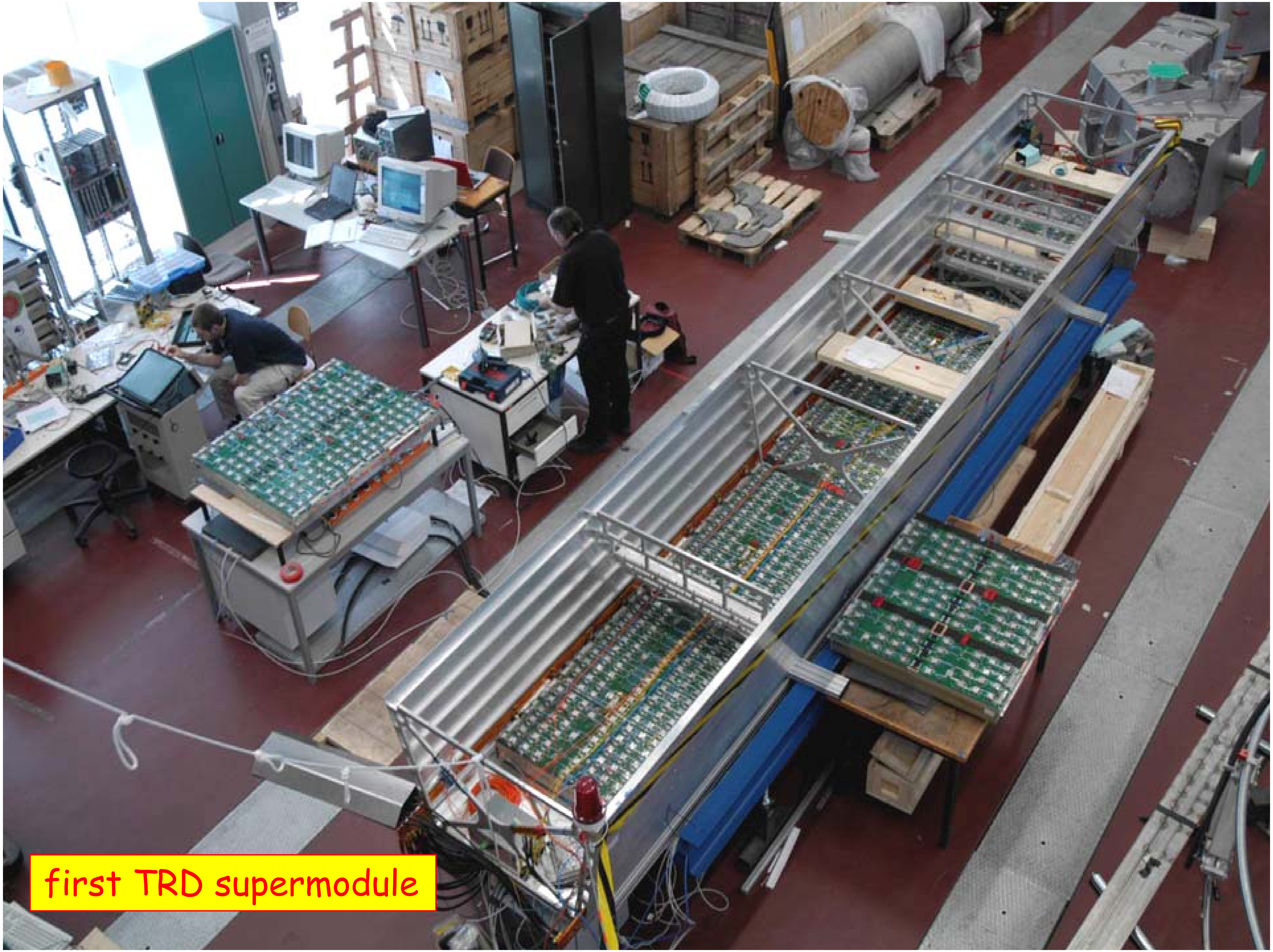
Fiber/foam sandwich
PP, 17μm

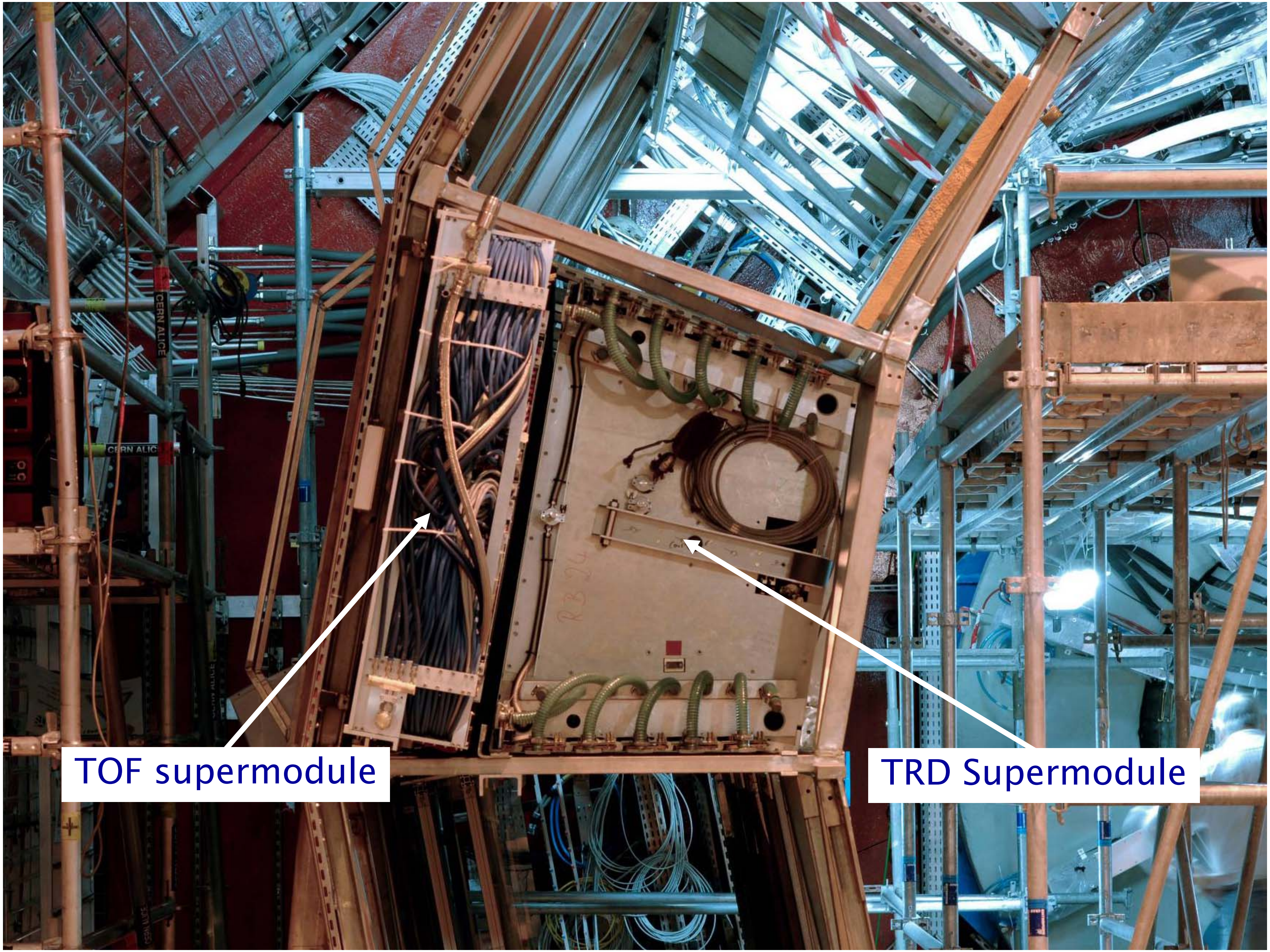
e/π–discrimination ~ 10^{-2}

For 90% e–efficiency



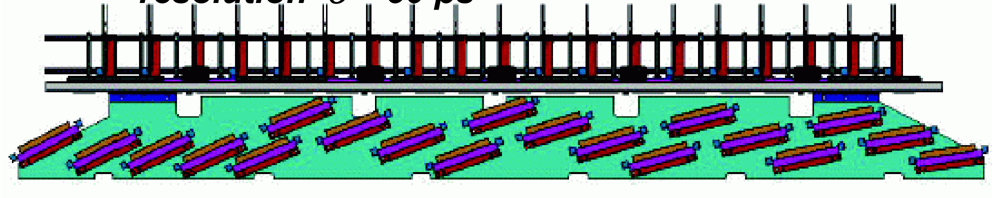


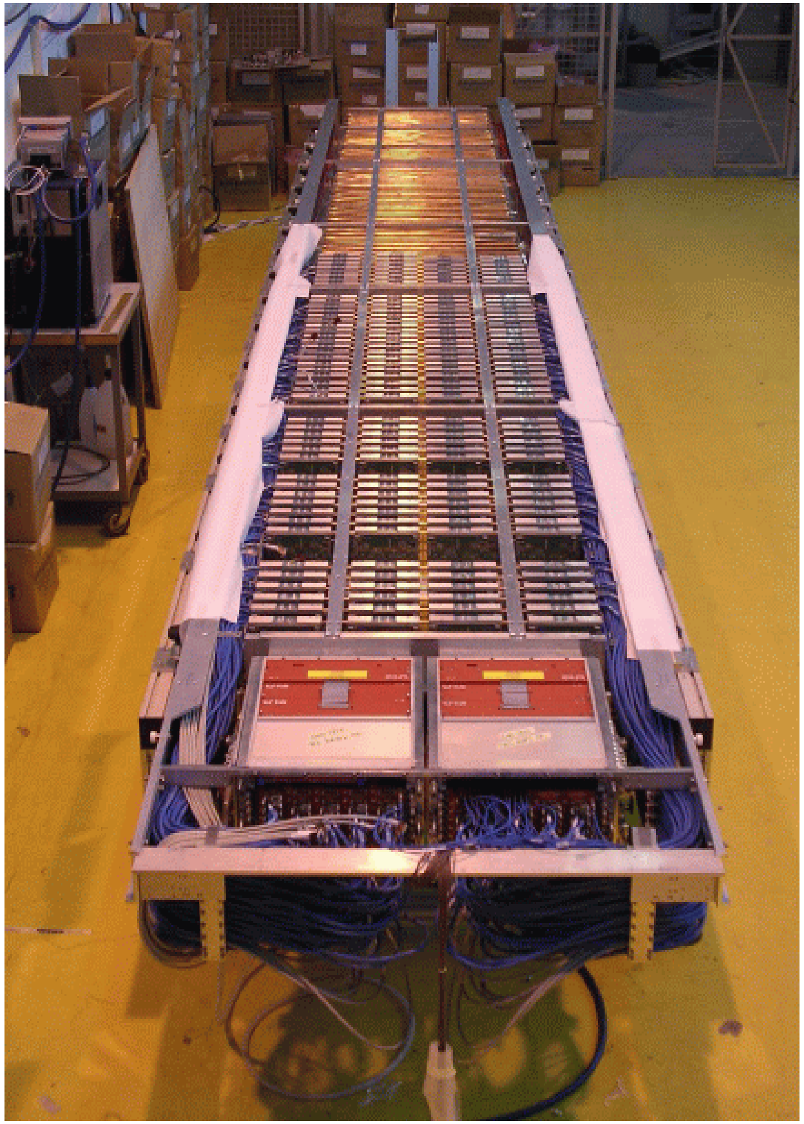

first TRD supermodule


TOF supermodule
TRD Supermodule
CERN ALICE

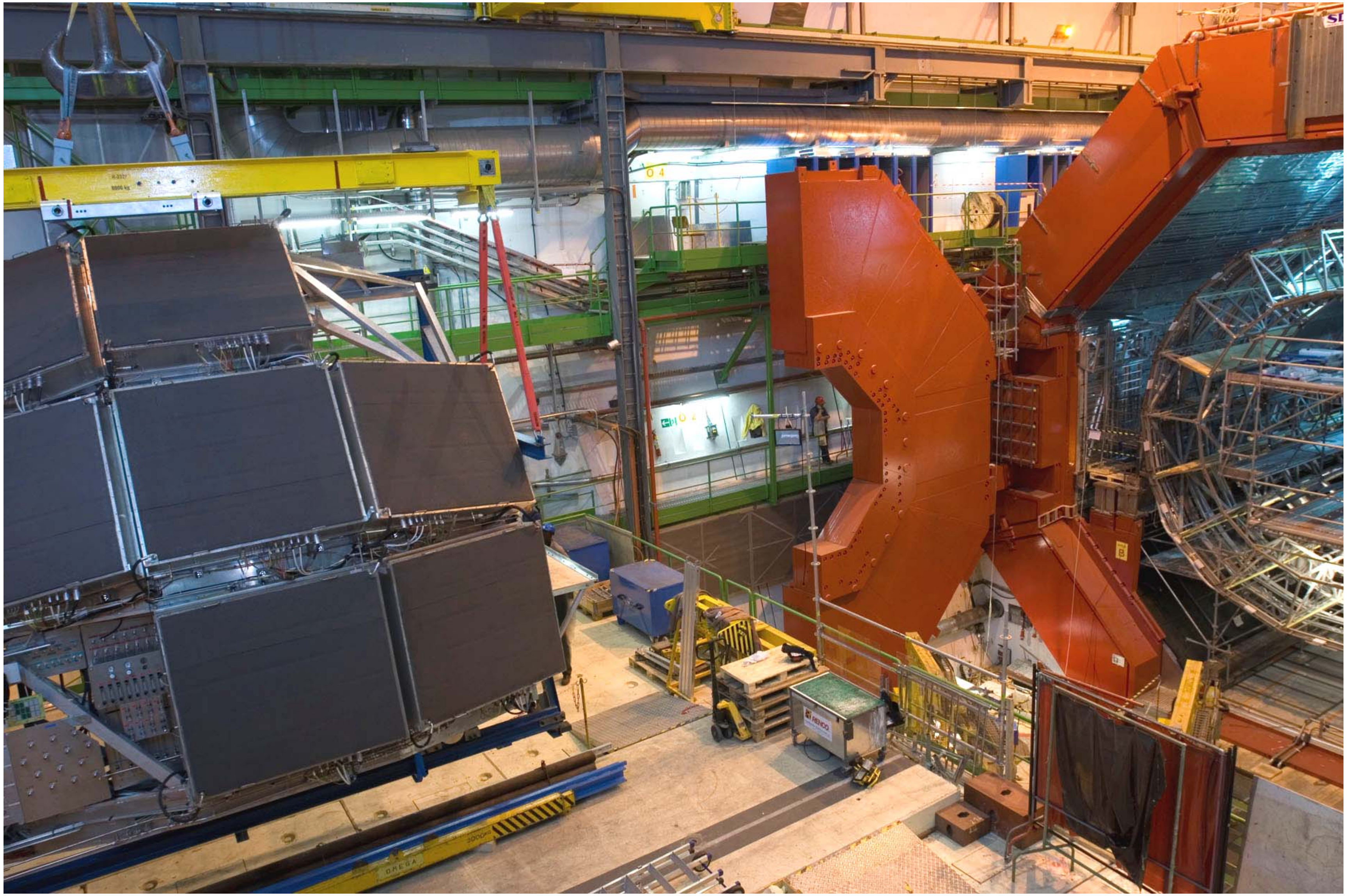
TOF

Multi-gap resistive plate chambers (MRPC)
gaps: 10 x 250 μm
channels: >8000 channels per SM
efficiency 99.6%
resolution σ ≈ 50 ps





High Momentum Particle Id (HMPID)



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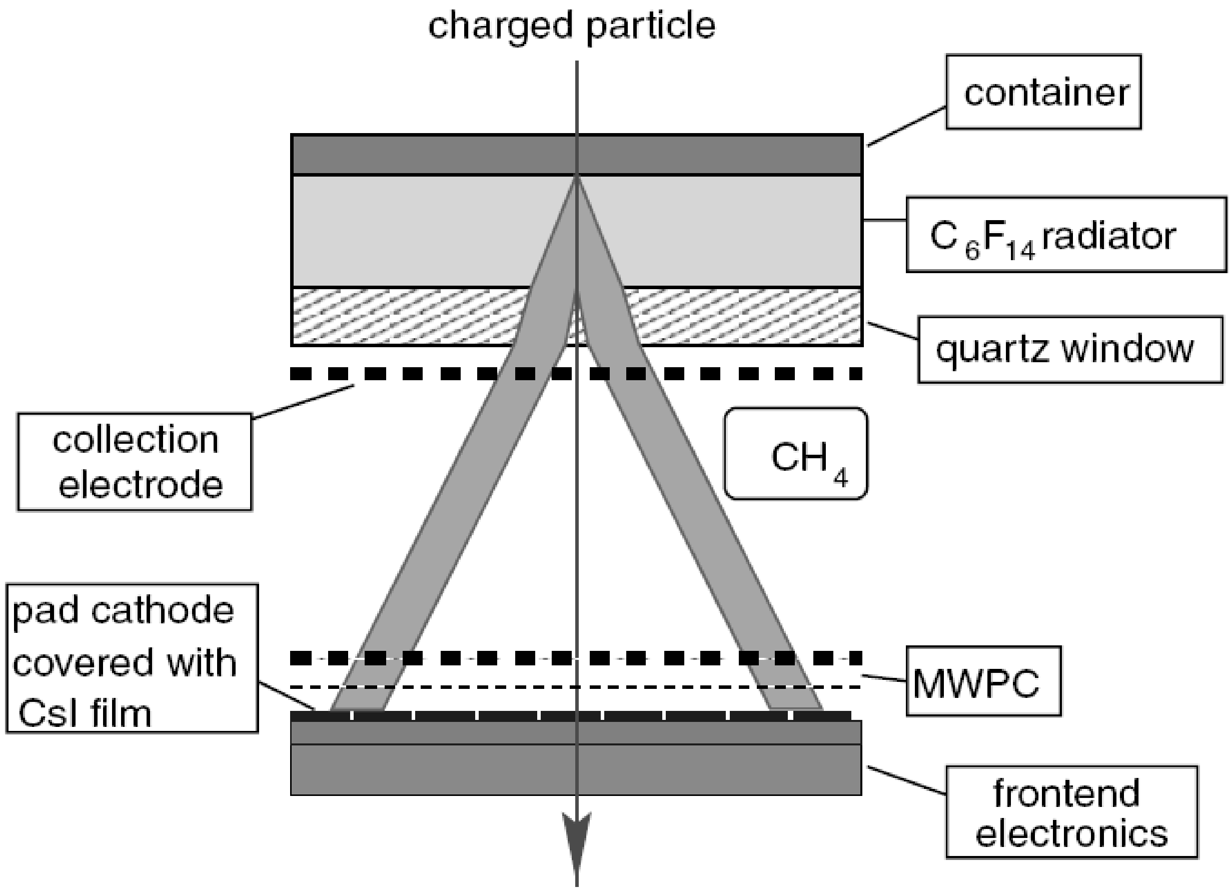
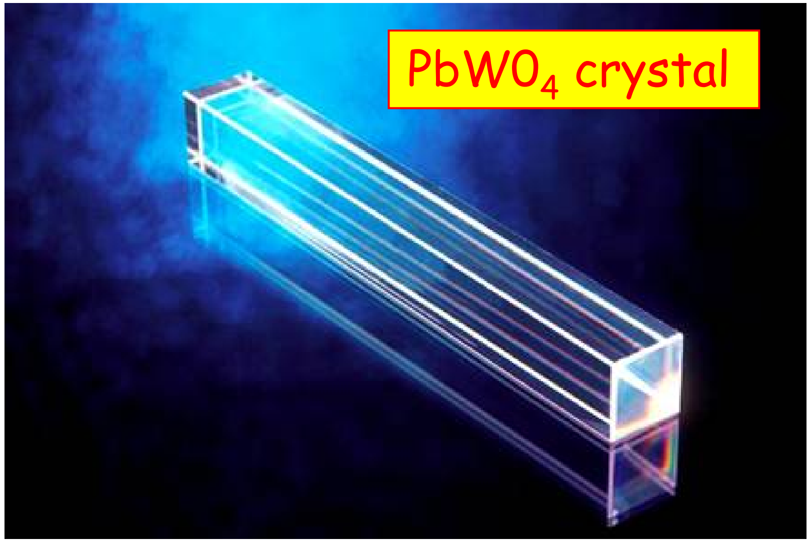


Photon Spectrometer (PHOS)



photons, neutral mesons, γ-jet tagging

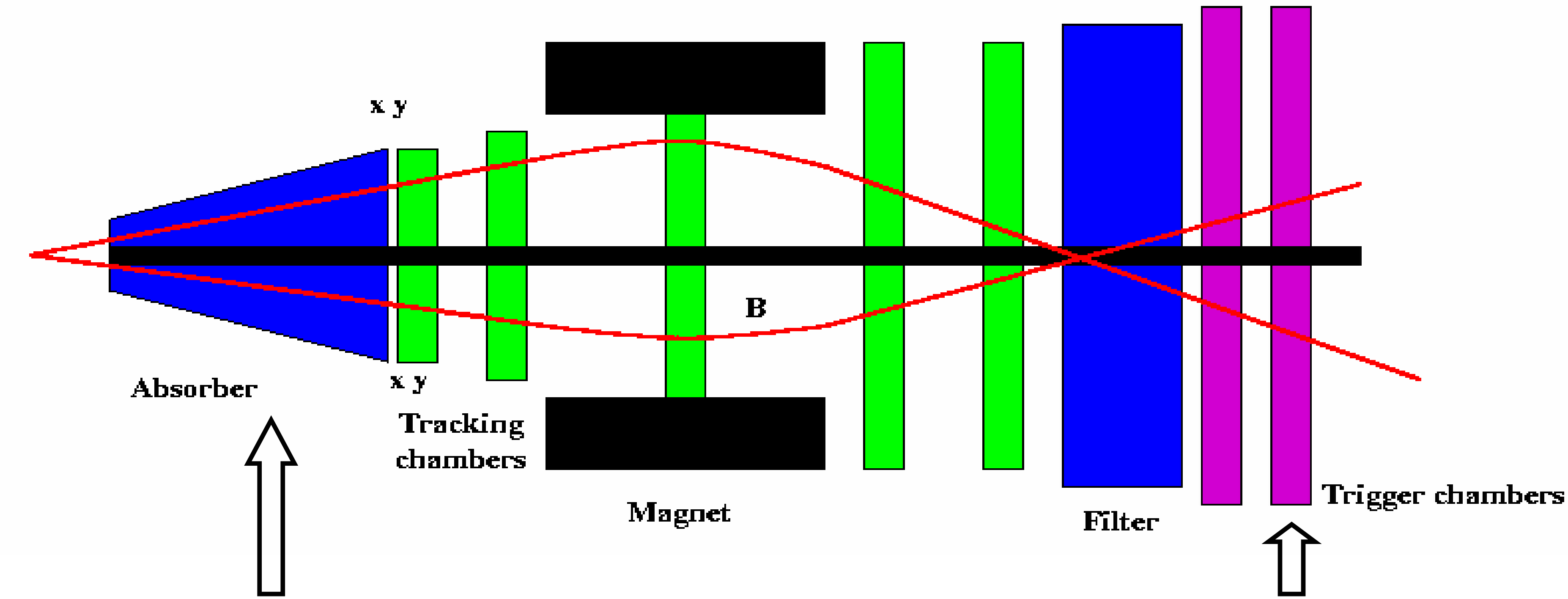
dense $PbWO_4$ crystals (X_0 < 0.9 cm) at -25˚C

~18k channels, 8m^2

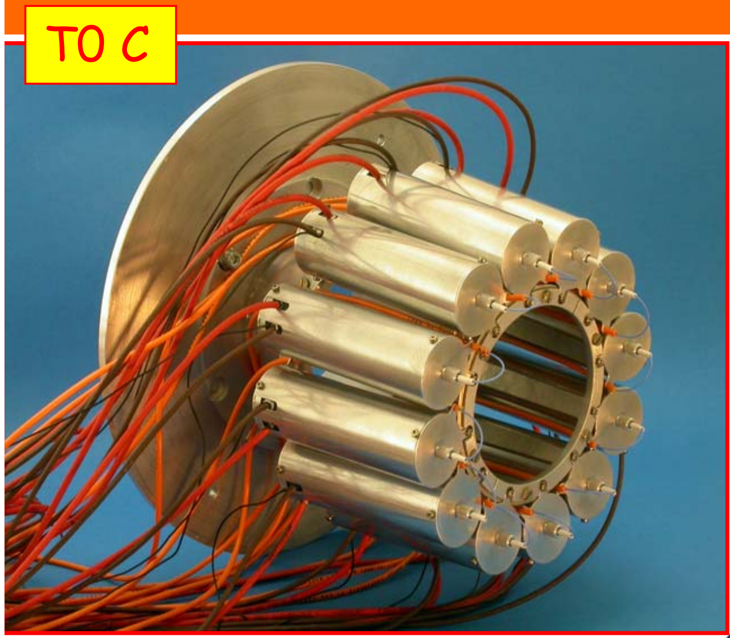
good energy resolution
- ***stochastic: 2.7%/√E***
- ***noise: 2.5%/E***
- ***constant: 1.3%***

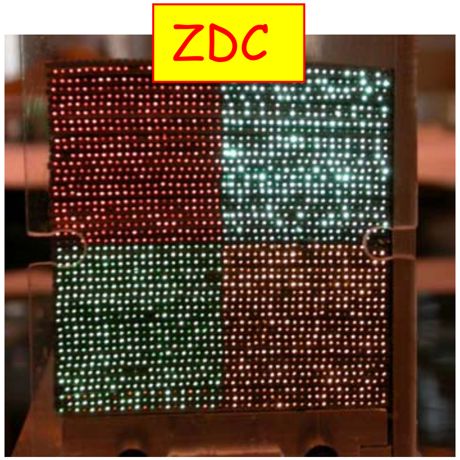
Forward Muon Spectrometer (MUON)

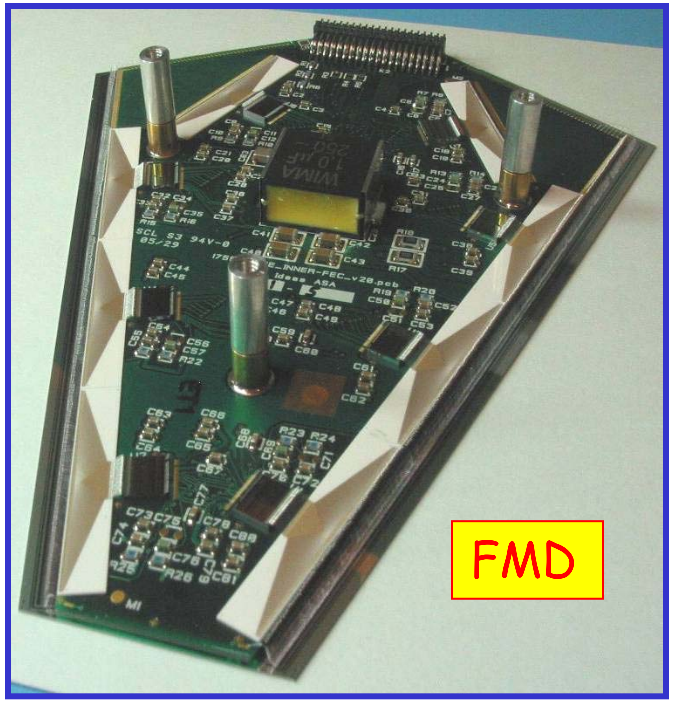
... aka Muon Arm

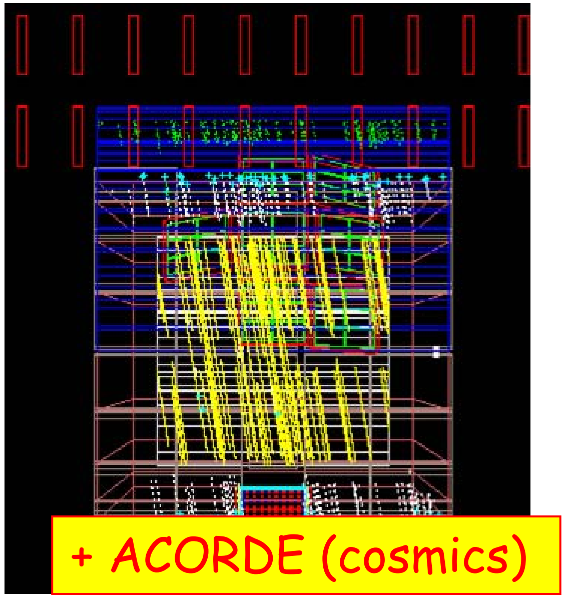


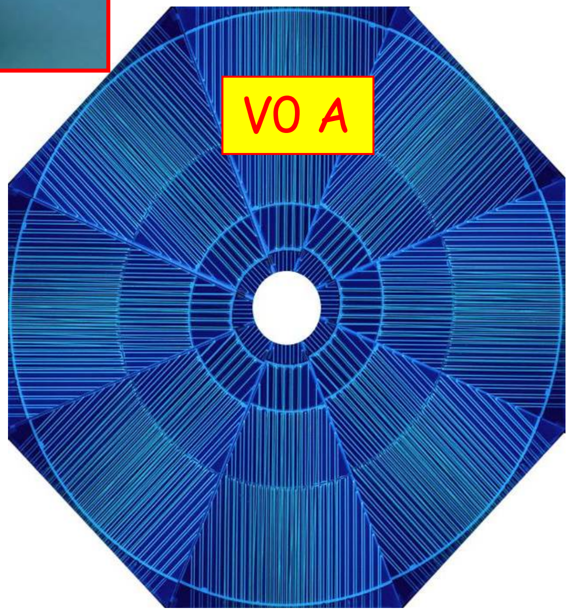
forward detectors

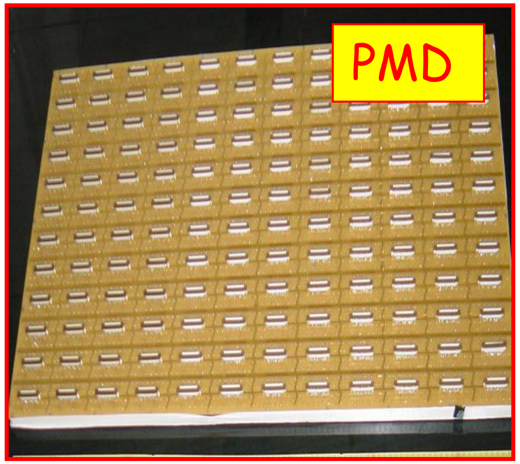












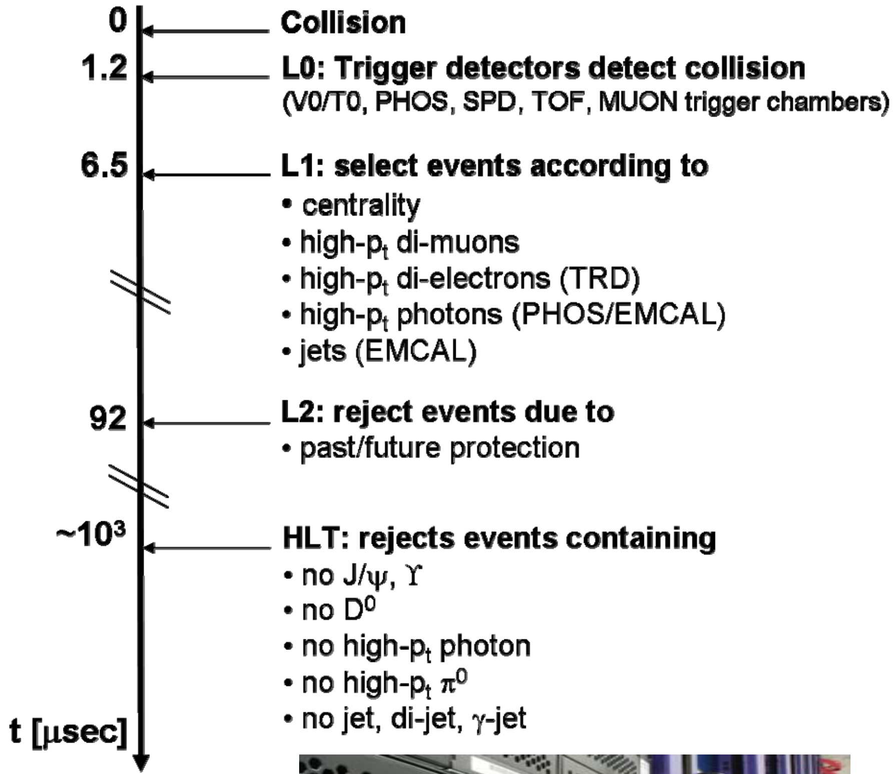
Trigger

Hierarchical architecture

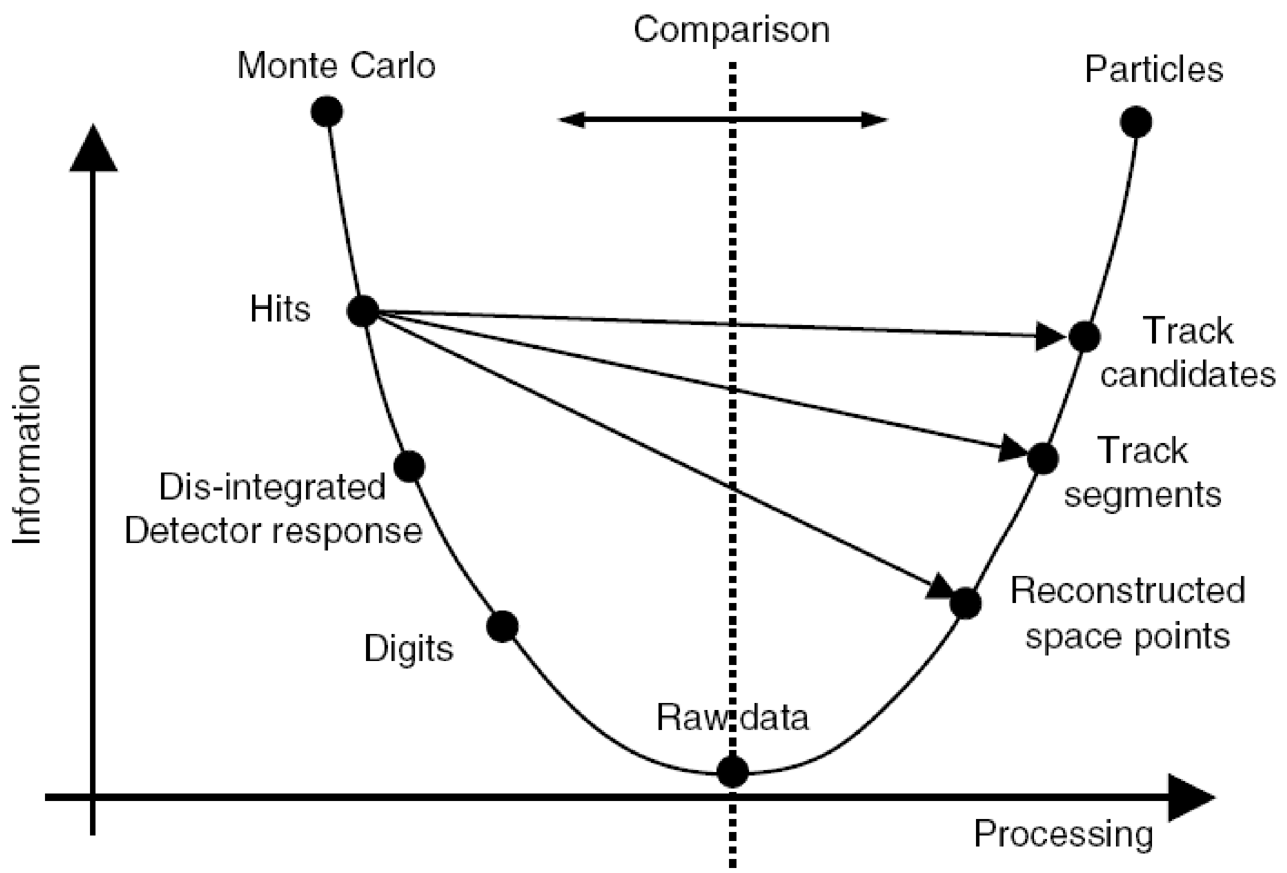
- L0, L1, L2, and HLT

High Level Trigger (HLT)

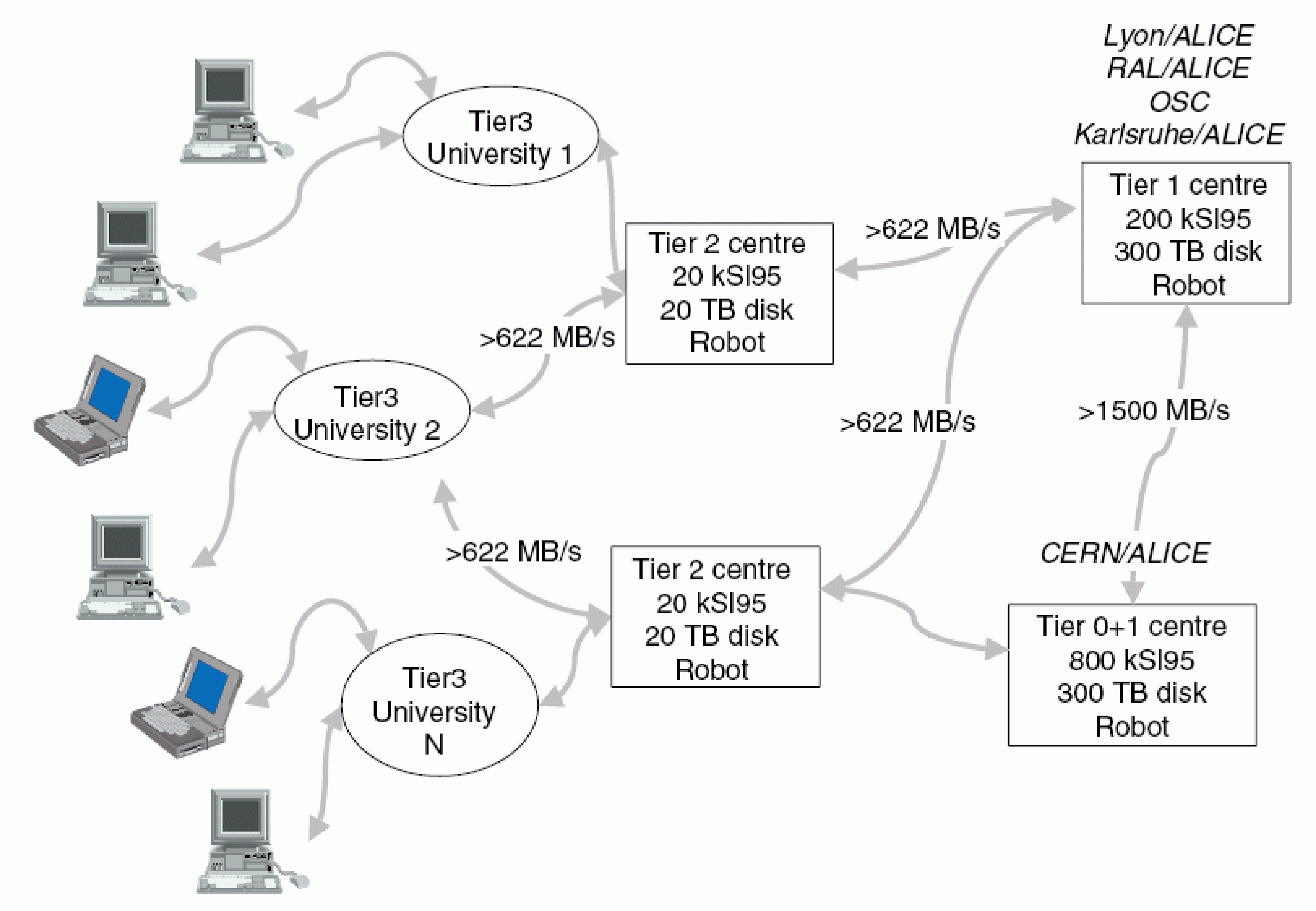
- Online reconstruction using ~500-600 PCs + FPGAs
- Input rate 200Hz (central Pb-Pb) → up to 20 GByte/s
- Generate physics trigger (e.g. jets, Upsilons, D^0, ...)
- Online data compression
- Calibration tasks



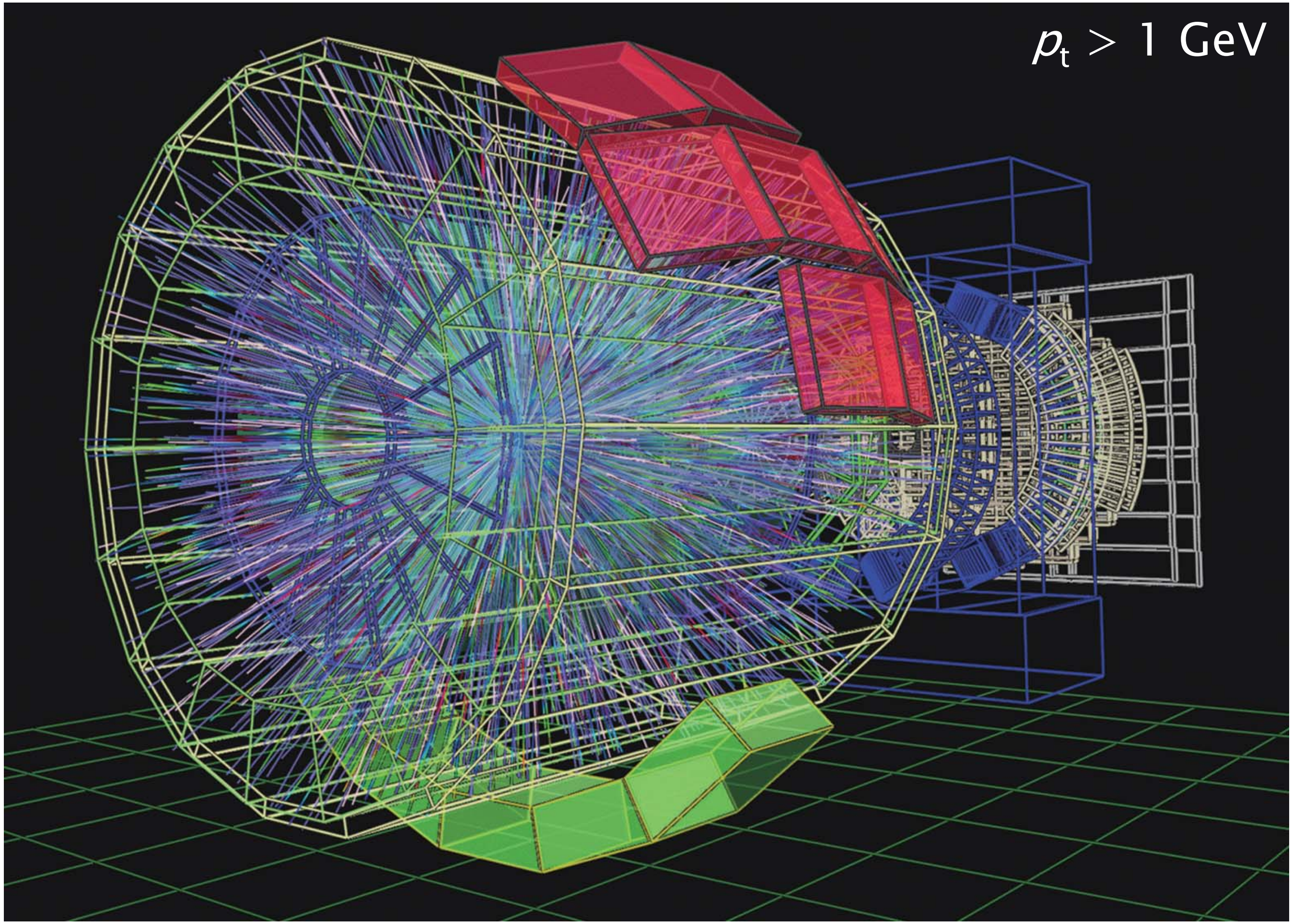
Data processing aka offline



Grid


Lyon/ALICE
RAL/ALICE
OSC
Karlsruhe/ALICE
Tier 1 centre
200 kSI95
300 TB disk
Robot
Tier3
University 1
Tier 2 centre
20 kSI95
20 TB disk
Robot
>622 MB/s
>622 MB/s
Tier3
University 2
>622 MB/s
>1500 MB/s
>622 MB/s
CERN/ALICE
Tier 2 centre
20 kSI95
20 TB disk
Robot
Tier 0+1 centre
800 kSI95
300 TB disk
Robot
Tier3
University
N

ALICE Event Display



central barrel tracking

Efficiency

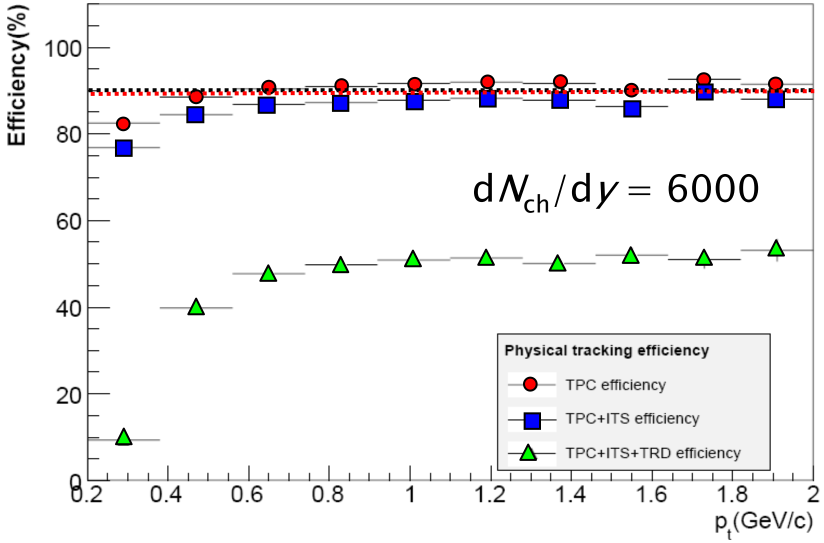
Approaches TPC acceptance (90%)

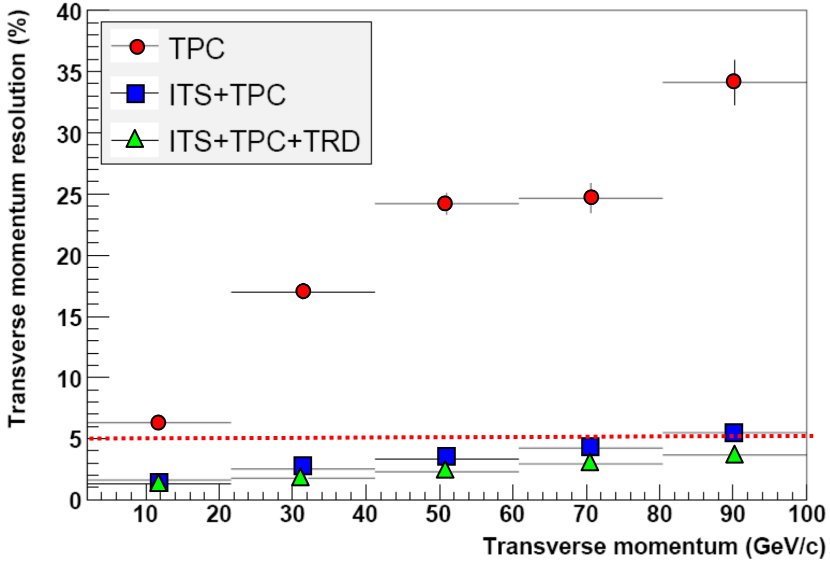
Only very little dependence on track multiplicity

Momentum resolution

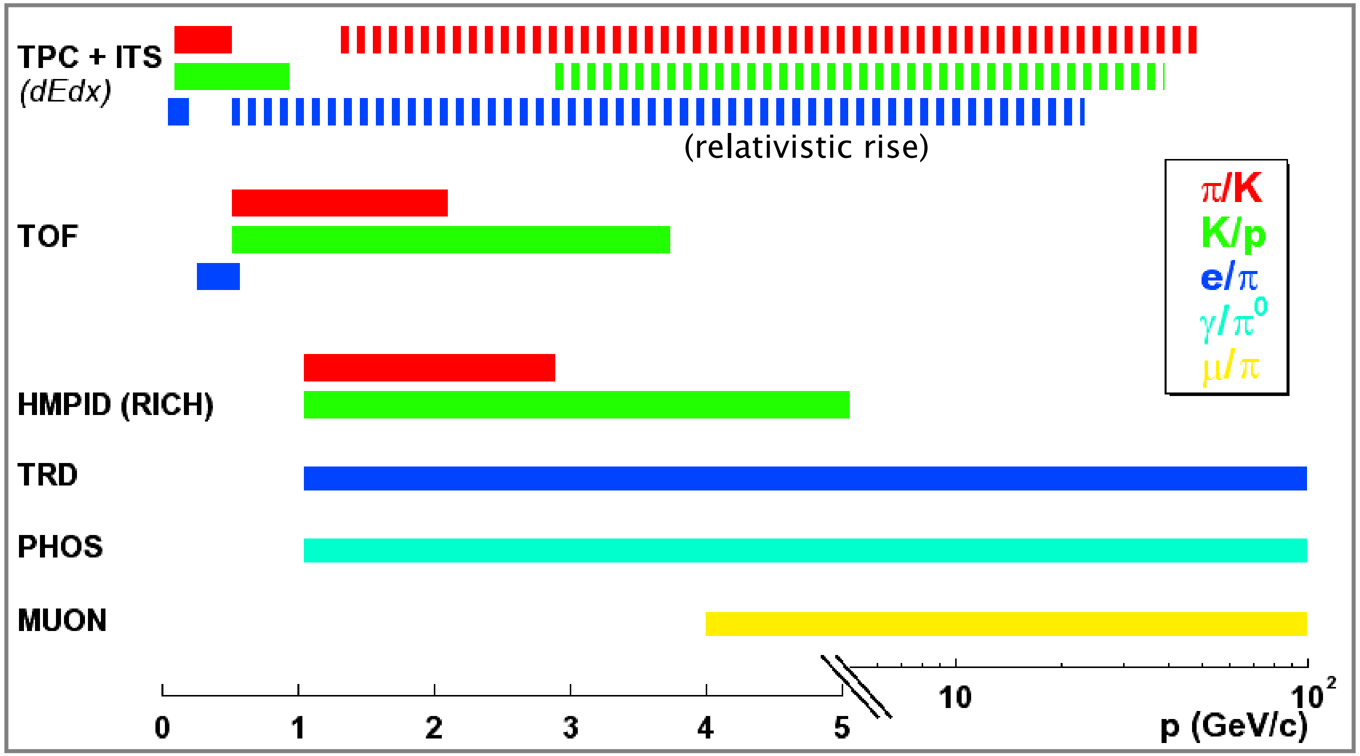
Long lever arm ITS + TPC + TRD (4cm < r < 3700cm)

$\delta p_t / p_t \leq 5\%$ at $p_t = 100$ GeV/c and $B = 0.5$T





PID Capabilities



TPC: $\sigma(dE/dx) = 5.5(pp) - 6.5(Pb\text{-}Pb)\ \%$

TOF: $\sigma < 100$ ps

TRD: π suppression $\approx 10^{-2}$ @ 90% e-efficiency

Day 1 @ LHC: event multiplicity at y=0

- generic trends in $dN^{ch}/d\eta$
  - extended longitudinal scaling
  - self-similar trapezoidal shape

$$\Rightarrow \left. dN^{ch}/d\eta \right|_{\eta=0} \propto \ln\sqrt{s_{NN}}$$

- Saturation models predict

Armesto, Salgado, Wiedemann, PRL94 (2005) 022002

$$\left. \frac{1}{N_{\text{part}}} \frac{dN^{AA}}{d\eta} \right|_{\eta\sim 0} = N_0 \sqrt{s}^{\lambda} N_{\text{part}}^{\frac{1-\delta}{3\delta}}$$

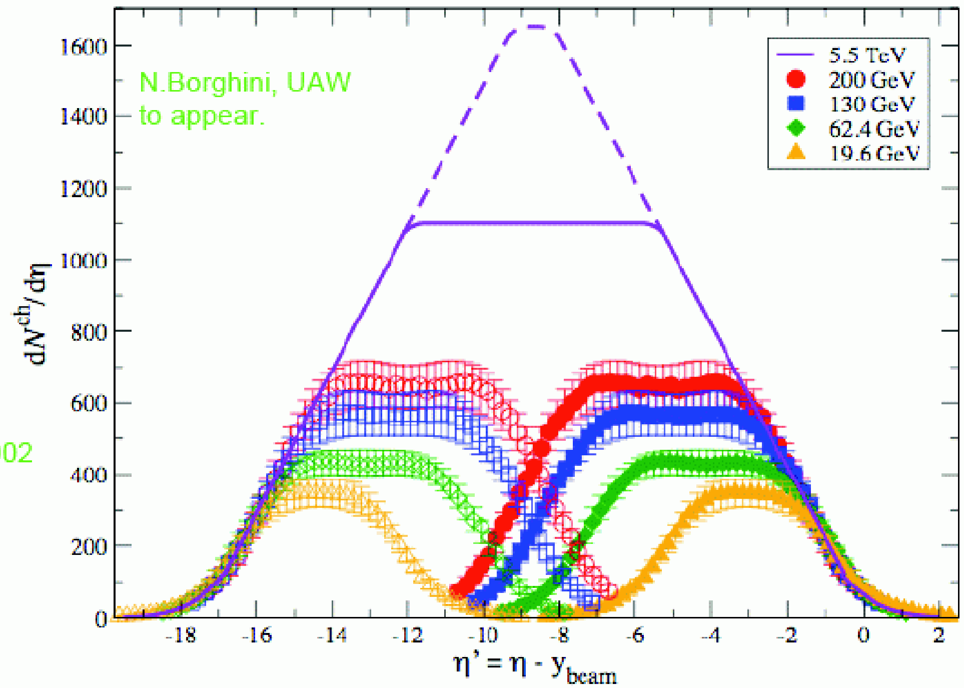
$$\Rightarrow \left. dN^{ch}_{LHC}/d\eta \right|_{\eta=0} \approx 1650$$

or Kharzeev, Levin, Nardi, NPA747 (2005) 609.

$$\Rightarrow \left. dN^{ch}_{LHC}/d\eta \right|_{\eta=0} \approx 1800 - 2100$$

Both consistent with main trends at RHIC, but …

PHOBOS, PRC74 (2006) 021901; W. Busza .



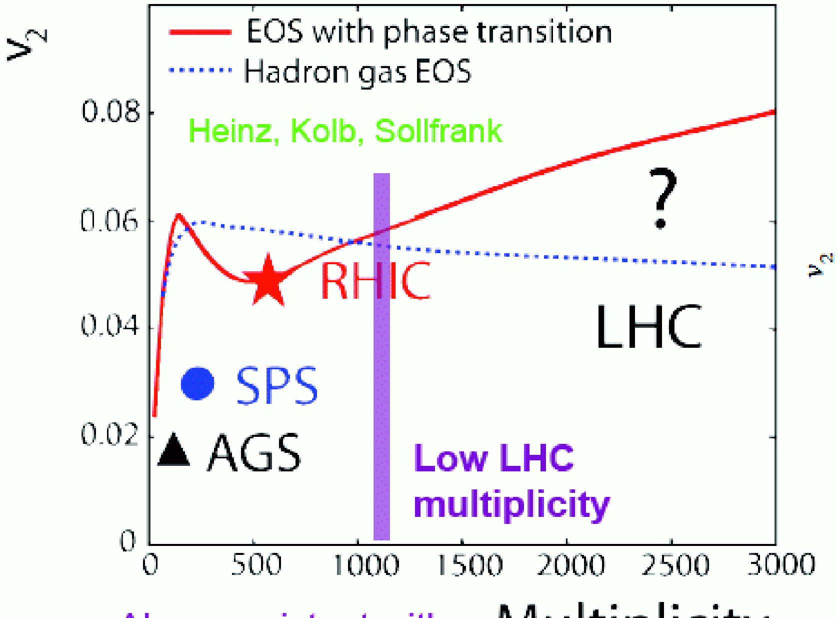
Extrapolations to LHC deviate from so-far generic trends in data

➡ Impact for understanding the dynamical origin of soft physics at RHIC and LHC.

LHC tests the hydro-paradigm

- Hydro prediction for low LHC multiplicity

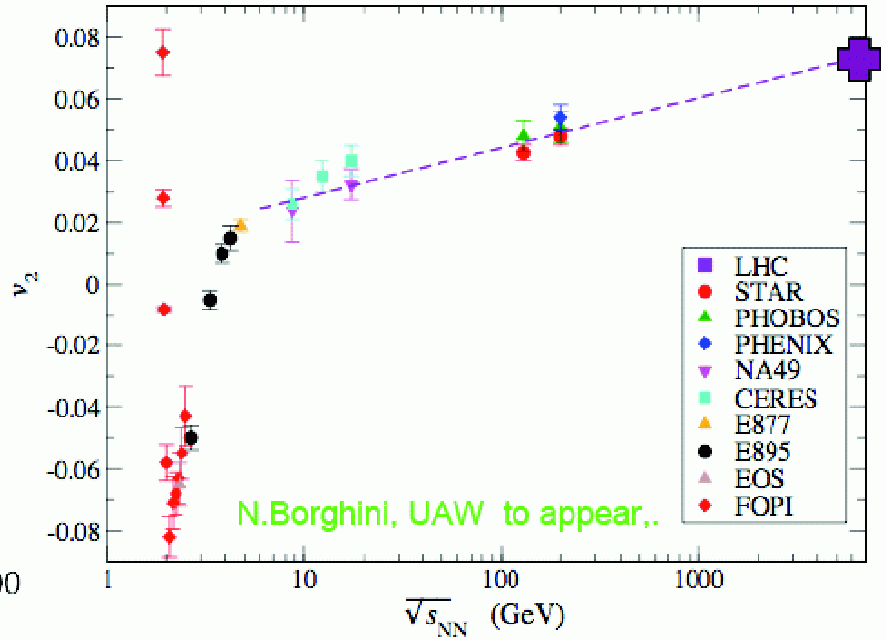
$$v_2 \approx 0.055$$



Also consistent with
Teaney et al., nucl-th/0110037

- Extrapolation of generic RHIC trend

$$v_2 \approx 0.075$$



(In)consistency with generic trend ⟷ Characterization of microscopic dynamics underlying collectivity

Open charm and beauty

goal:
measure parton energy loss in QGP

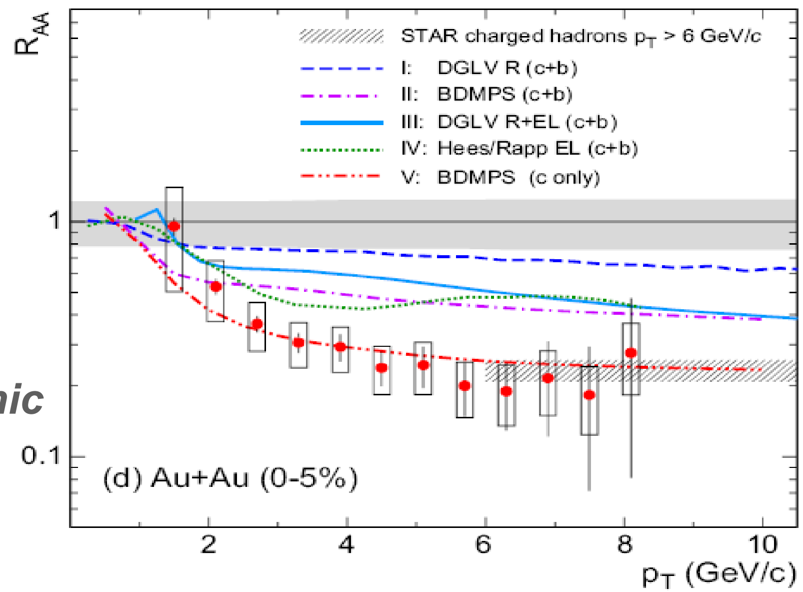
expectation:
energy loss color dependent (different for quarks and gluons)

energy loss flavour dependent (smaller for heavy quarks)

advantage at LHC:
high abundance of c and b (direct reconstruction possible)

c/b

System	p+p	Pb+Pb (5% cent)
$\sqrt{s_{NN}}$ (TeV)	14	5.5
NN cross section (mb)	11.2 / 0.5	6.6 / 0.2
Shadowing	---	0.65 / 0.85
Total multiplicity	0.16 / 0.007	115 / 4.6



RHIC: Non-photonic electrons used to estimate charm

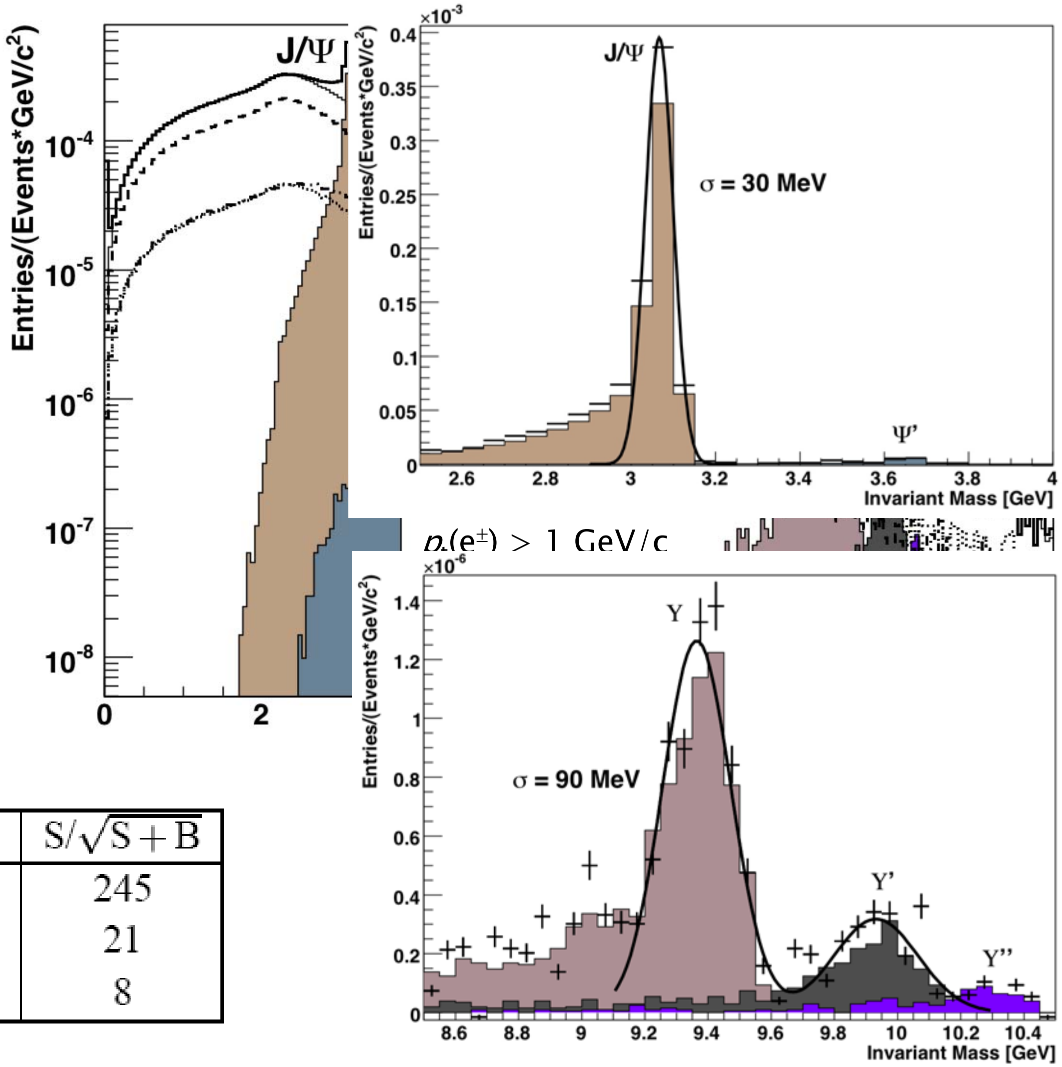
Quarkonia in dielectron channel

Central barrel

ITS+TPC+TRD
$-0.9 < \eta < 0.9$

e-ID with TRD

Resolution:
$\sigma_m(J/\psi) \approx$ 30MeV
$\sigma_m(\Upsilon) \approx$ 90MeV



Di-electron in central barrel

State	S ($\times 10^3$)	B ($\times 10^3$)	S/B	$S/\sqrt{S+B}$
J/ψ	110.7	92.1	1.2	245
Υ	0.9	0.8	1.1	21
Υ′	0.25	0.7	0.35	8

Quarkonia in dimuon channel

MUON-arm

Forward region
$2.4 < \eta < 4.0$

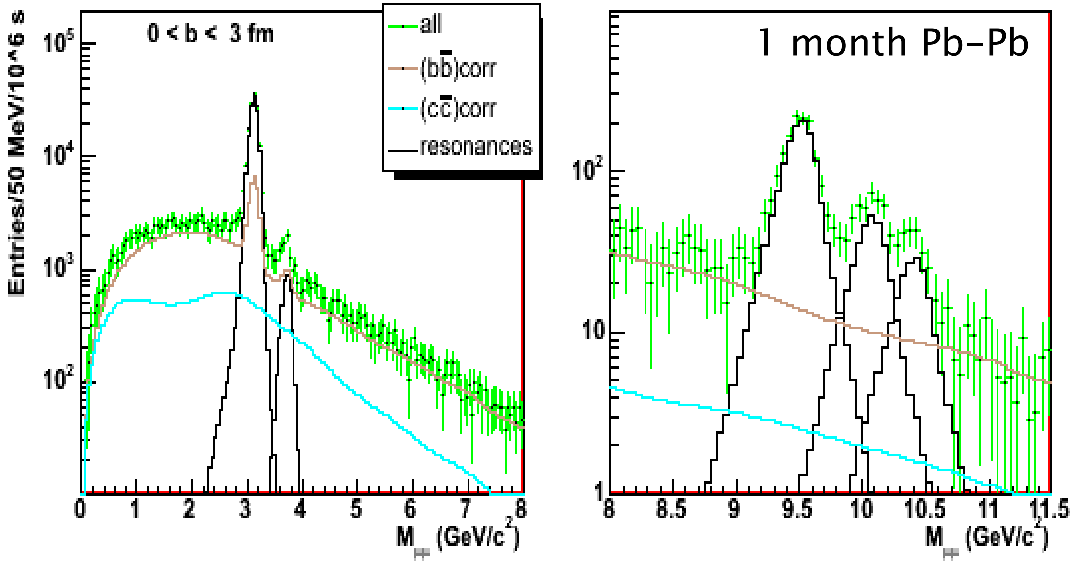
Resolution:
$\sigma_m(J/\psi) \approx$ 70MeV
$\sigma_m(\Upsilon) \approx$ 100MeV

Sensitivity
$(e^+e^-/\mu^+\mu^-)$

J/ψ, Υ, Υ' : High with normal stat.

Υ'': Needs 2-3 years high lum.

ψ' : Difficult



State	S[10³]	B[10³]	S/B	S/(S+B)^1/2
J/Ψ	130	680	0.20	150
Ψ'	3.7	300	0.01	6.7
Υ(1S)	1.3	0.8	1.7	29
Υ(2S)	0.35	0.54	0.65	12
Υ(3S)	0.20	0.42	0.48	8.1

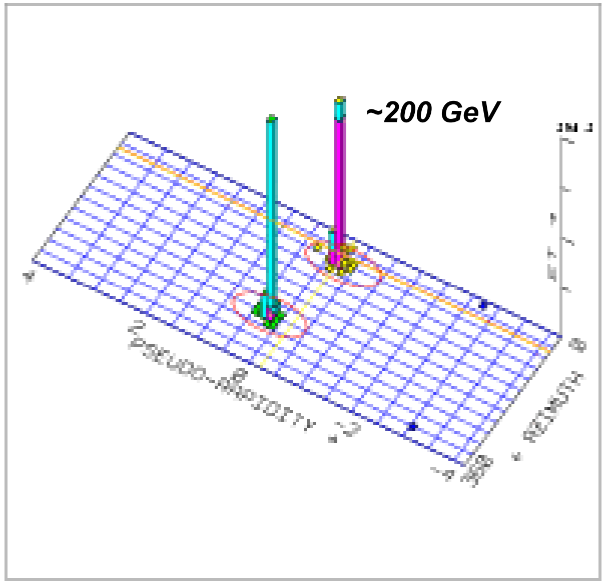
Jets

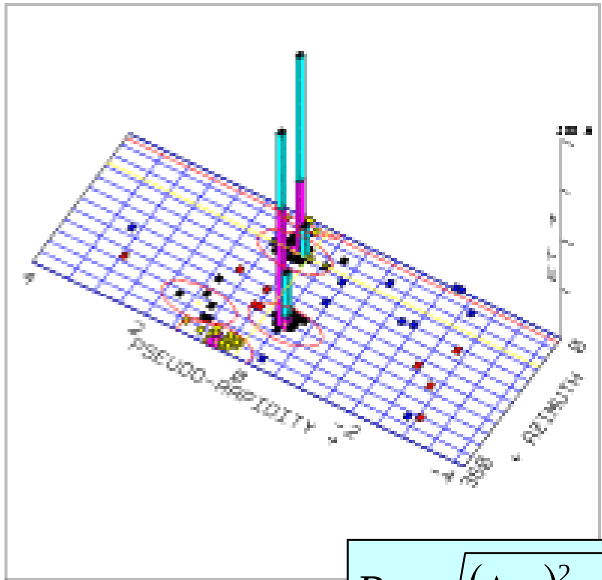
1 month of running	
$E_T >$	N_{jets}
50 GeV	2.0×10^7
100 GeV	1.1×10^6
150 GeV	1.6×10^5
200 GeV	4.0×10^4

- pp vs. PbPb
- calorimetry vs. charged tracks
- triggering
- suppression

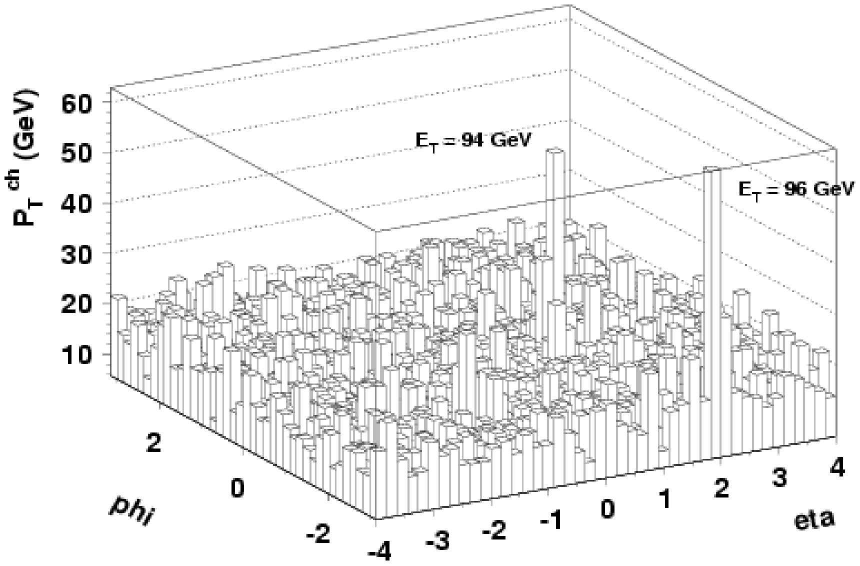
jets in p+pbar at 1.8 TeV

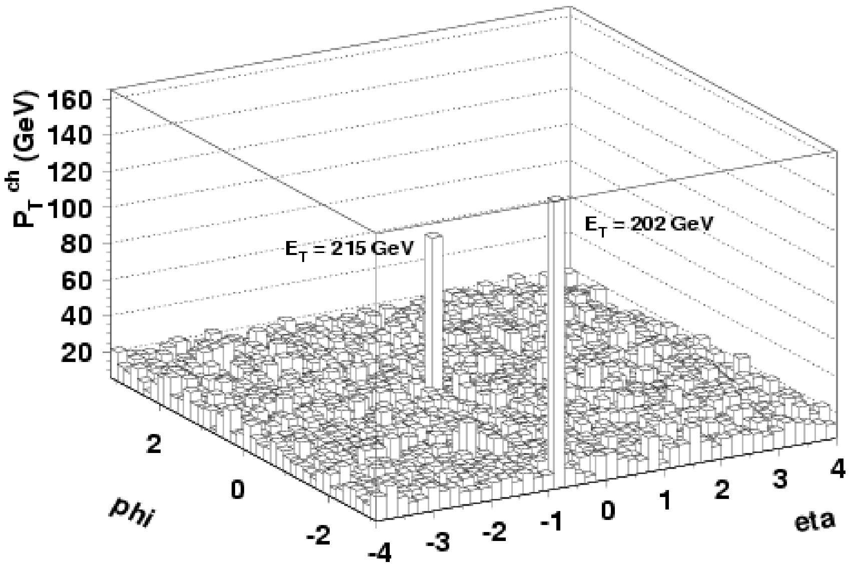
CDF, PRD 64 (2001) 032001





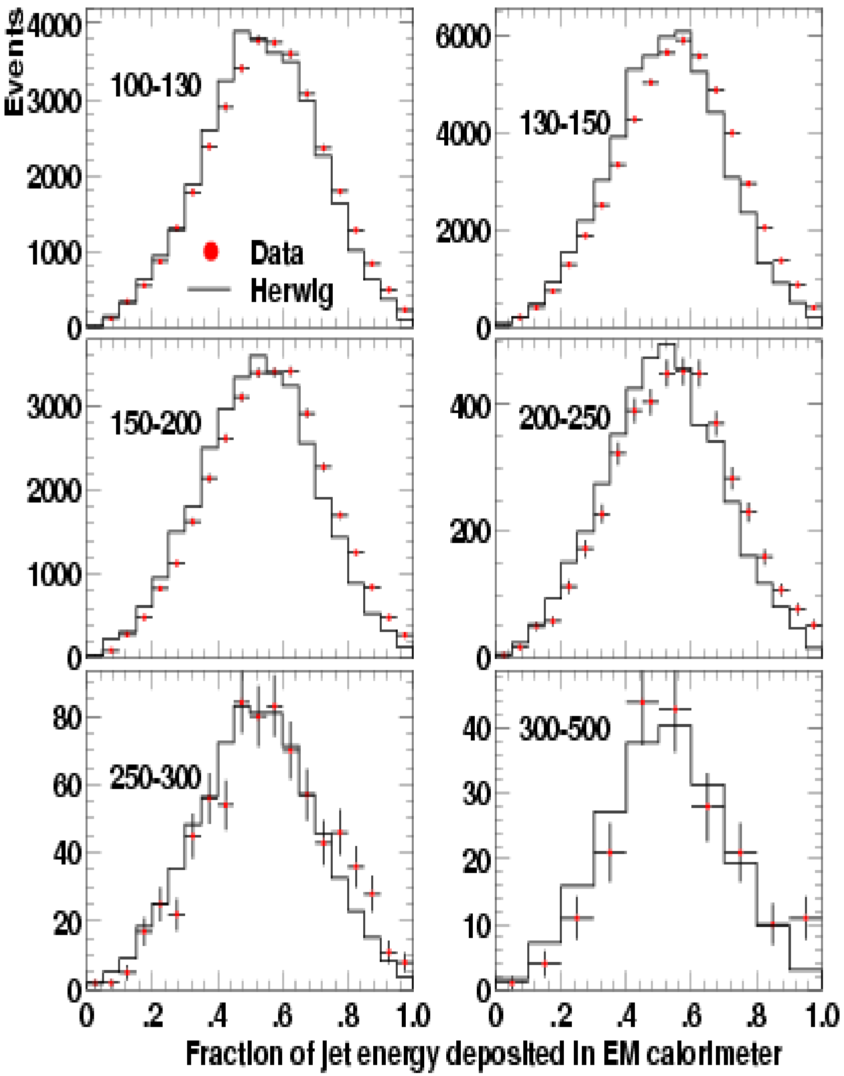
jets in Pb+Pb at 5.5 TeV (ALICE sim)



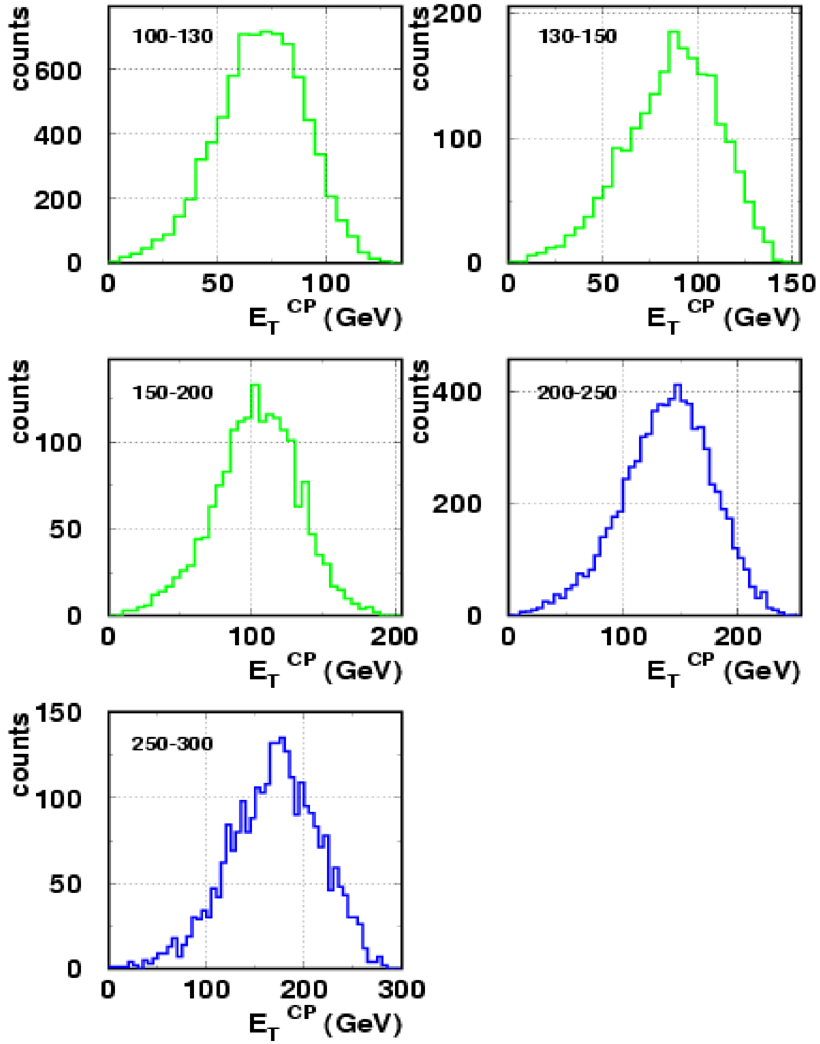


$$R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

jets with an EM calorimeter (CDF)

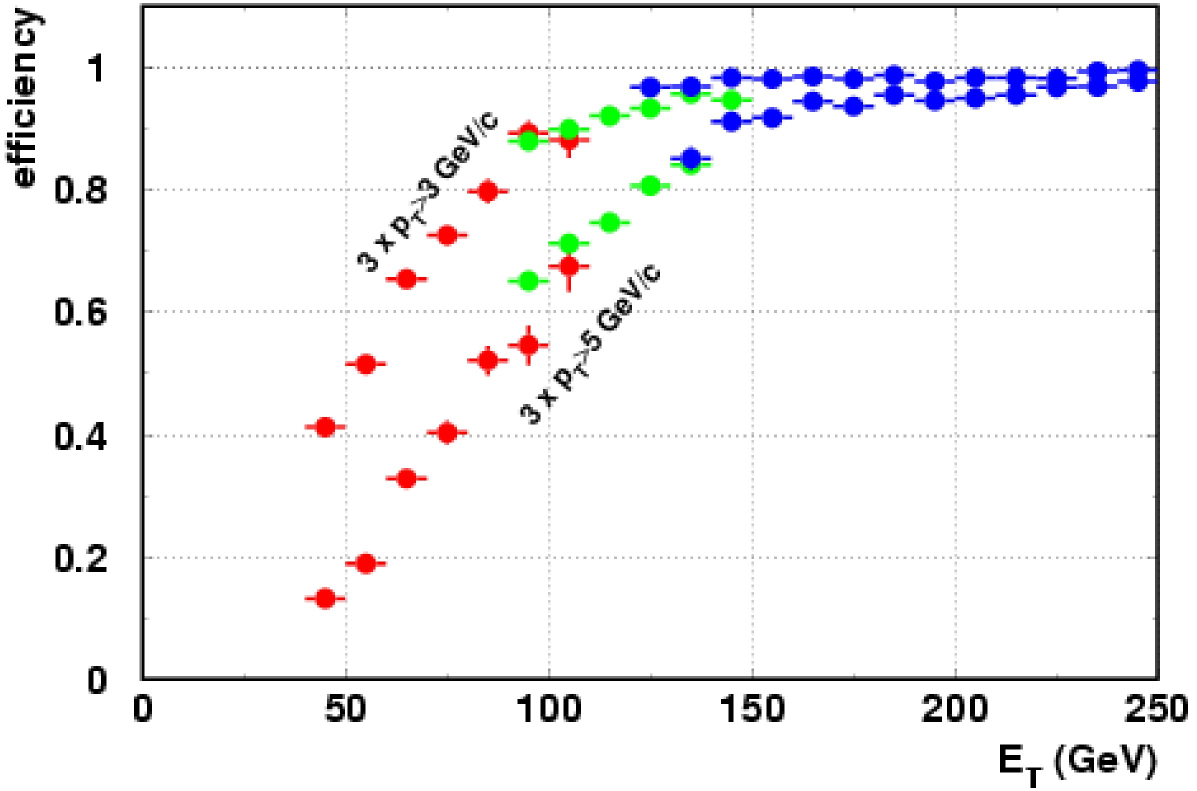


jets with charged particles (ALICE ITS+TPC+TRD)



fraction of jet energy in form of charged particles

Jets with ITS, TPC, TRD – TRD trigger

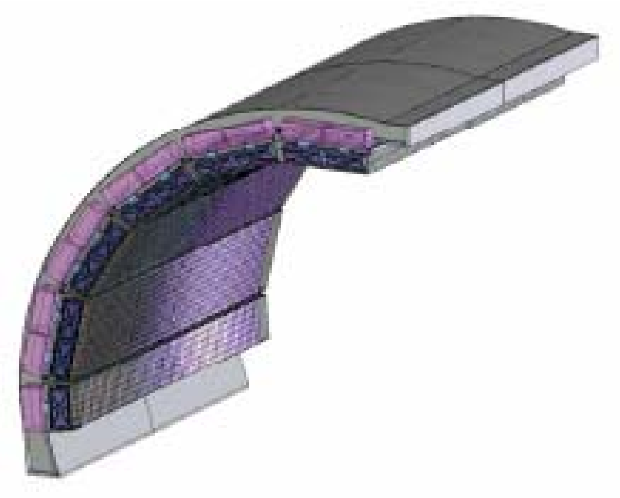


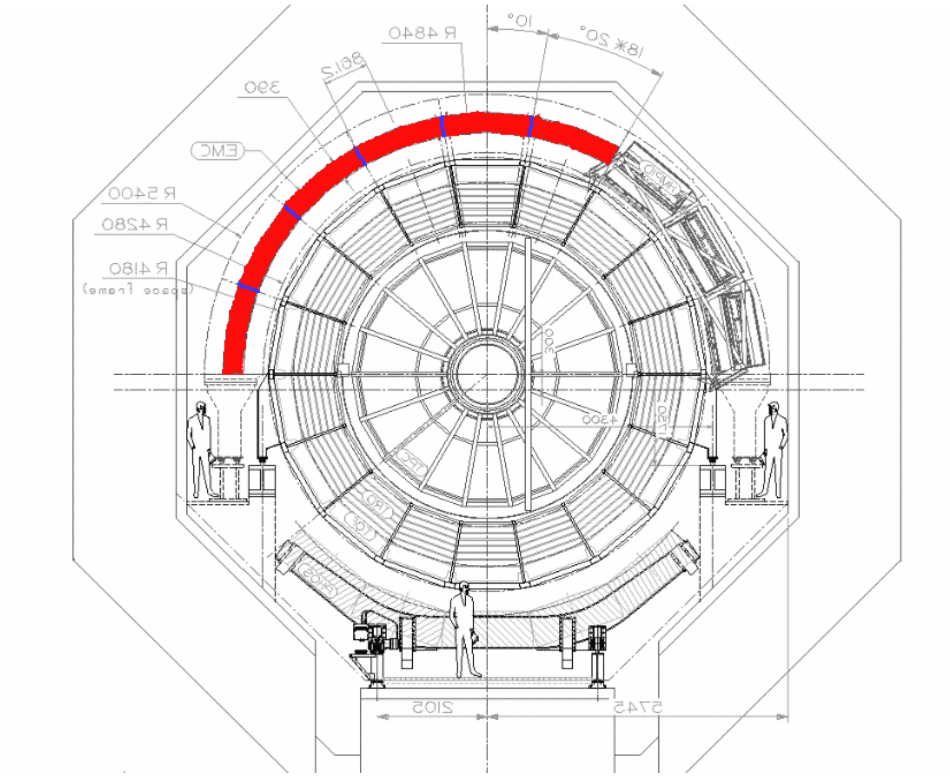
trigger condition:

3 charged particles with $p_T > p_T min$ in one TRD module

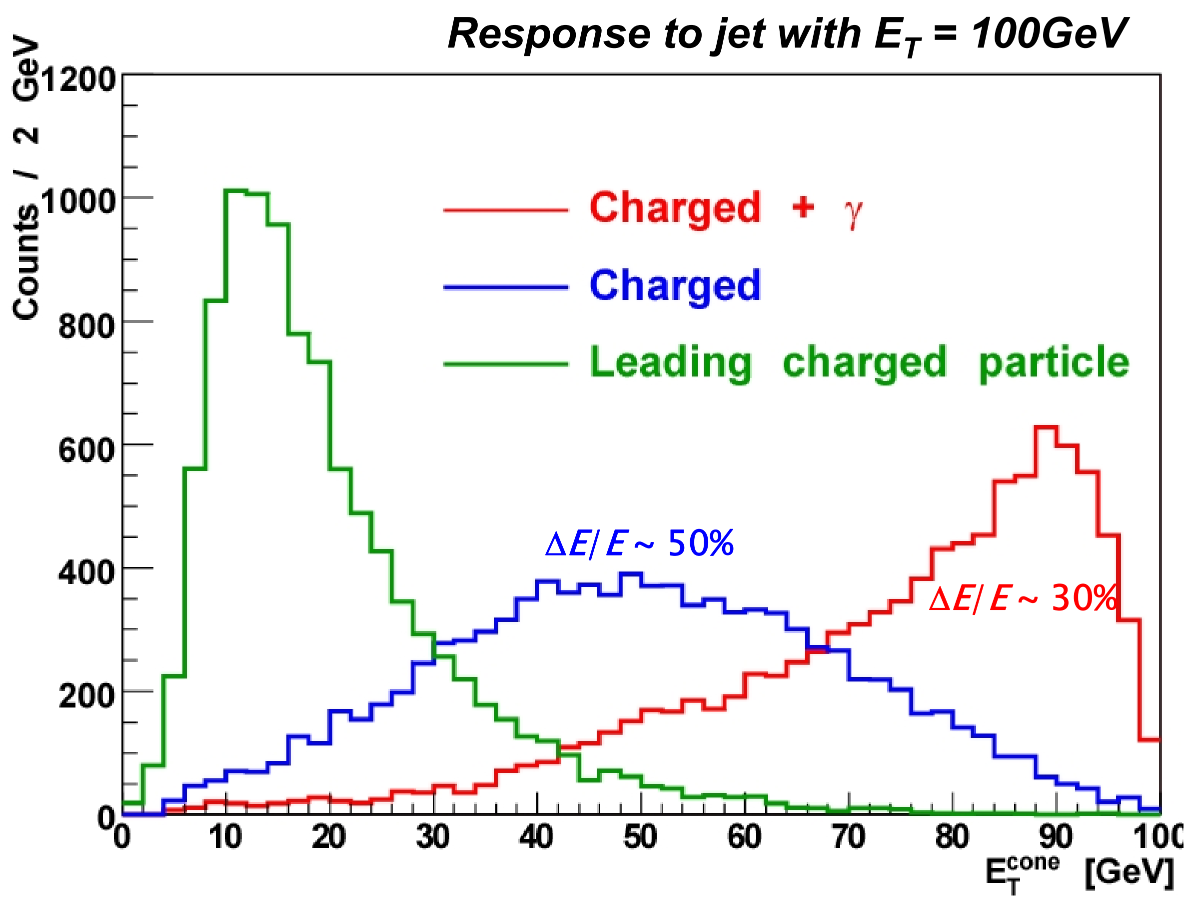
Jets with EMCAL

- EM Sampling Calorimeter - latest addition to ALICE by US, France, Italy
- Pb-scintillator linear response
  $-0.7 < \eta < 0.7$
  $60^o < \phi < 180^o$
- Energy resolution ~15%/√E





Jets with both



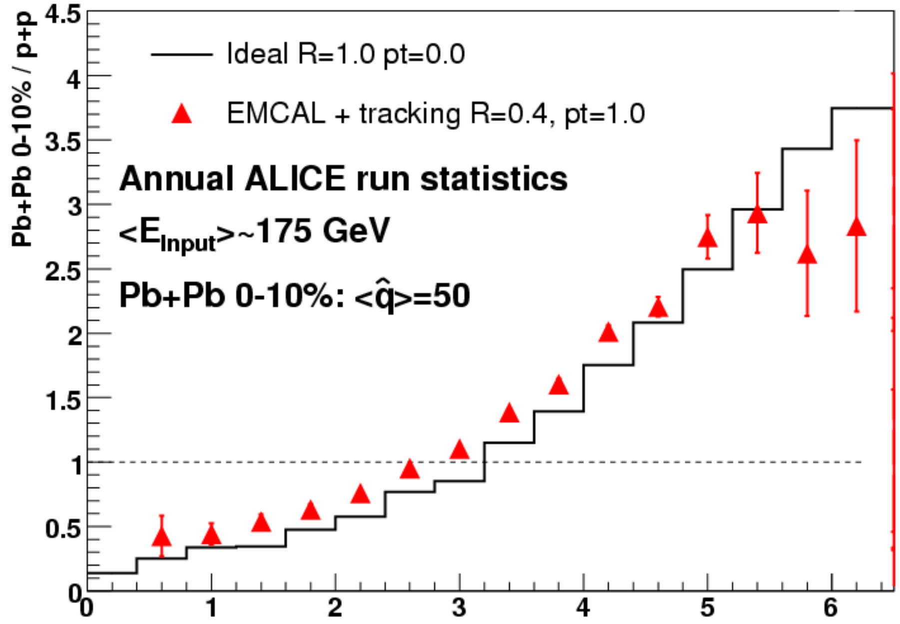
Jet fragmentation function

Sensitive to energy loss mechanisms

- Quenching of leading hadron
- Additional hadrons by gluon radiation
- Transverse heating

Observable:

- Ratio of fragmentation functions: $\frac{FF\,(\mathrm{Pb+Pb})}{FF\,(\mathrm{p+p})}$



$$\xi = \ln\left(\frac{1}{z}\right) = \ln\left(\frac{E_t^{jet}}{p^{hadron}}\right)$$

ALICE general running plans

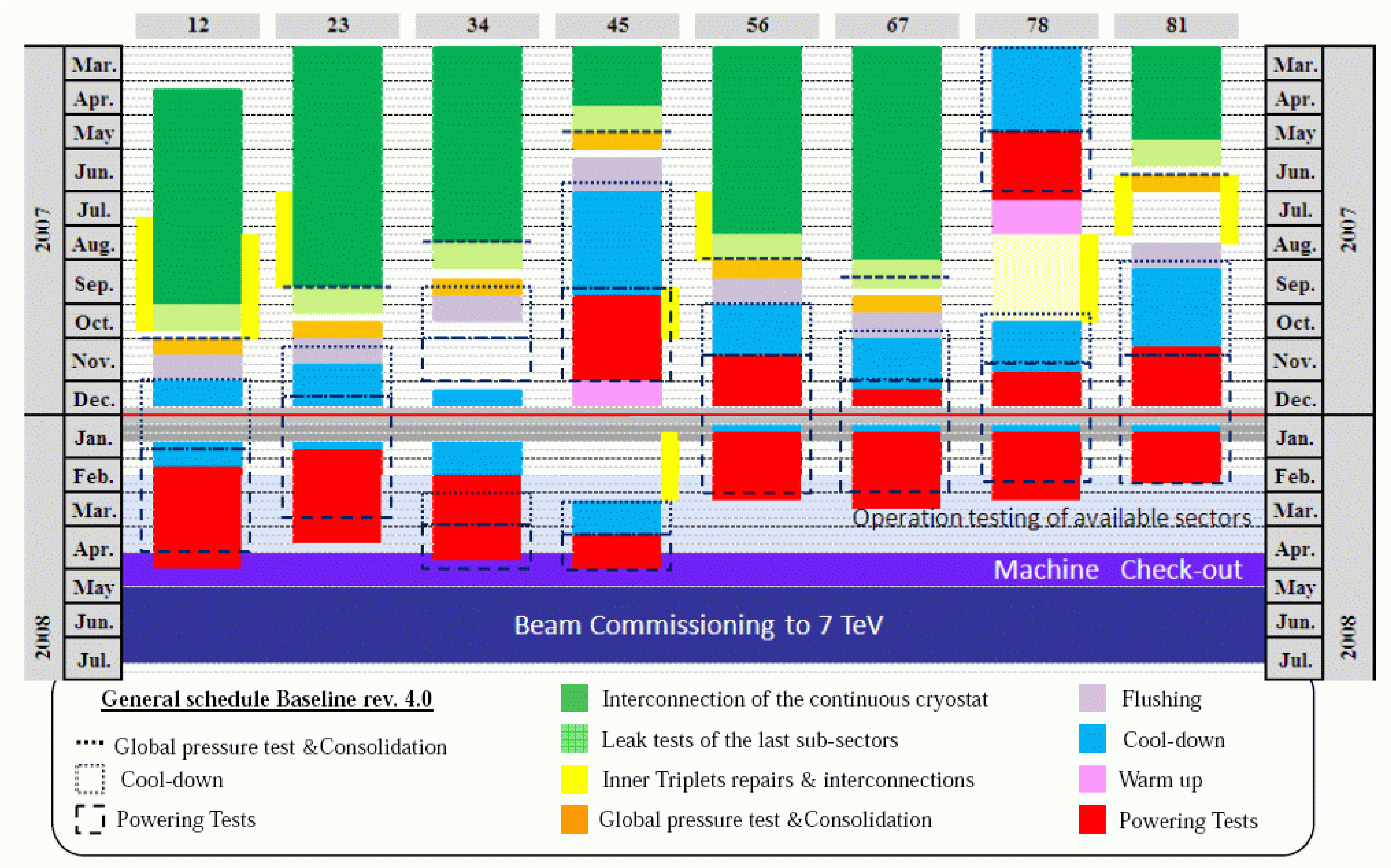
initial phase

- *pilot Pb+Pb*
- *1-2 years Pb+Pb*
- *1 year p+Pb (or like)*
- *1-2 years Ar+Ar*

subsequent options

- *pp at sqrt(s) = 5.5 TeV*
- *N+N or O+O or Kr+Kr...*
- *another pA*
- *lower energy Pb+Pb*
- *high stat full energy Pb+Pb*

LHS schedule as of Aug-2007



ALICE status Sep-2007

ACORDE: installed. DAQ, DCS, ECS connection ongoing

EMCAL: support ready to be installed.

FMD: 2/3 installed

HMPID: installed, going to measure cosmics

MUON: nearly completely installed

PHOS: first module under test with cosmics on the surface, installed in Nov

SDD: installed, tests ¾ done.

SPD: installed, electronics tests

SSD: installed, electronics tests and debugging

ALICE status Sep-2007

TOF: sm0 and sm8 installed, cosmics

TPC: parking position because of ITS, long term electronics tests

TRD: sm8 installed, sm0 soon ready to be installed

T0: C-side installed (electronics not yet). A-side installed in Jan

V0: C-side installed (electronics not yet). A-side integrated with FMD3 in Oct, installed in Jan

ZDC: first ZDC installed, second one being installed now

***Startup configuration for 2007*:**

complete ITS, TPC, HMPID, MUON arm, PMD, V0, T0, ZDC, Accorde

partial PHOS(1/5), TOF(9/18), TRD (2-3/18), DAQ (20%)

Summary

Heavy ion physics will do a big step ahead with LHC startup

Era of precision measurements of the QGP matter

ALICE will be ready for data taking with the first pp run

Experimental setup is multi-purpose and flexible

Summary of *foreseen* ALICE physics:

ALICE Physics Performance Report, Vol. II,
J. Phys. G32 (11), 2137 (2006)